BLASTERS' HANDBOOK

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Blasters' Handbook

A MANUAL DESCRIBING EXPLOSIVES AND PRACTICAL METHODS OF USING THEM

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PREPARED BY

THE TECHNICAL SECTION
OF THE
EXPLOSIVES DEPARTMENT

ELEVENTH EDITION

E. I. DU PONT DE NEMOURS & COMPANY (INC.)

EXPLOSIVES DEPARTMENT

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PREFACE

Each day, in a multitude of ways, explosives serve all industry and enter into all phases of modern living. They play an important role in prospecting for raw materials and fuels and they are indispensable in the production of the vast amounts of these required by industry. Explosives are essential for mining coal, metals and other minerals; for quarrying stone, and for developing oil and natural gas resources. In forest and field they assist in the production of lumber and agricultural products. They are used to widen and deepen channels, to divert rivers and streams and to produce the materials required to dam them; thereby assisting in the utilization of waterways for transportation, power, irrigation, and domestic and industrial water supplies. Travel and transportation by land rely heavily on explosives to shape the routes by leveling and penetrating natural barriers, and providing the materials to ballast and pave the right-of-ways. In short, explosives have some bearing on every phase of human enterprise and are involved in the fabrication of nearly all of man's creations.

The uses of explosives are so diversified that a mere list would be imposing and a comprehensive discussion of each application an almost impossible undertaking. The purpose of this handbook is to furnish a convenient source of information on explosives and their more frequent applications. Its scope is intended to be general, and while information is given on a variety of specific uses, it has not been possible to treat them all in detail. Further information on blasting problems may be obtained by referring inquiries to the du Pont Company.

Experience indicates that the procedures described in this handbook are preferred practices covering the widest general applications. It is true that other procedures are also used

and occasionally in specific instances they may be superior to those recommended. It should be pointed out, however, that such departures are rare and specialized. The distinction between good practice and bad is not always obvious and all but experienced blasters should avoid unproved innovations.

It should be pointed out further that some of the practices recommended in this Eleventh Edition are at variance with those described in one or more previous editions. While those previously recommended are satisfactory when used in accordance with the procedures specified, records have shown that in many cases the warnings issued in connection with these practices have not been heeded. Experience indicates that following the modified practices recommended in this edition will make for improved performance. Undoubtedly, future experience will lead to still further changes.

Explosives Service

EXPLOSIVES must not only be properly made—they must also be promptly delivered, suitably stored, safely handled and efficiently used—all at minimum cost to the consumer.

During the one hundred and forty years that the du Pont Company has manufactured explosives, it has built up an organization and a fund of experience that enable it to meet every requirement of explosives manufacture and service. Its explosives research laboratory—the largest and best equipped in the world—insures the high quality and constant improvement of du Pont products. Du Pont branch offices, plants and magazines, widely distributed throughout the United States, provide prompt delivery wherever explosives are used; and a staff of technically trained men, each with years of practical blasting experience, is always at hand to assist du Pont customers in getting efficient results on the job.

Thus behind all du Pont explosives, blasting supplies and accessories stands "Du Pont Explosives Service"—an assurance of products of scientific excellence and quality, plus prompt delivery and capable technical assistance in the field.

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INTRODUCTION

Commercial explosives are mixtures of solids and liquids which are capable of extremely rapid and violent decomposition when they are initiated. Explosive decomposition can occur through deflagration, which is rapid burning or combustion as in the case of black powder, or detonation, which is an almost instantaneous disruption as in the case of dynamites.

Explosive decomposition, whether it be the rapid burning of black powder or the practically instantaneous detonation of dynamite, is simply a rearrangement process. The ingredients break up from their initial solid or liquid state and recombine to form other materials which are mostly gaseous and which occupy a great deal more volume than the explosive did originally. Furthermore, this decomposition and rearrangement liberates large amounts of heat, expanding the gases and causing them to exert enormous pressure. This pressure, which is developed almost instantaneously, enables the explosive to do the work for which it is designed. The energy released by an explosion is exerted equally in all directions but naturally, it will escape along the path of least resistance. Therefore, the profitable utilization of this power requires that it be applied skilfully.

The blaster must decide the kind and quantity of explosive to use. He must know how and where to drill and load the holes, what initiators to use and how to use them. Above all he must know how to work safely.

He may choose the explosive from the following classifications: (1) black powder, either blasting or pellet powder, (2) the commercial high explosives known as dynamites including straight and ammonia types, gelatins, semi-gelatins, and per-

missibles, and (3) the blasting agent "Nitramon." The types of explosives and the various grades of each type constitute an imposing list. Yet each grade has its own characteristics, properties, and range of practical applications.

The blaster also has a wide choice of supplies and accessories to enable him to carry on his job in the most efficient manner. His selection of these will be governed by a number of conditions. The job may be a small blast or a large one. It may be dry or completely under water, or anywhere between these two extremes. It may require igniters or detonators, single or multiple shooting, electric or non-electric firing, or the use of "Primacord."

The use of explosives is an art requiring specialized knowledge, experience, and the use of sound judgment.

CHAPTER I

BLACK POWDER

Black powders are deflagrating or "low explosives." This classification differentiates black powders both in composition and properties from detonating or "high explosives" such as the dynamites. A deflagrating explosive is one that burns progressively over a relatively sustained period of time in comparison with a detonating explosive which decomposes practically instantaneously.

Black powders are the slowest acting of all of the explosives. They have a shearing, non-shocking, heaving action tending to blast material into large, firm fragments. Their action derives from a relatively slow development of gas pressure so that they must be carefully loaded and closely confined. Burdens should be well balanced since there is a tendency for them to yield at the weakest point. Boreholes should be well tamped to prevent the escape of the gases and thus increase the effectiveness of the blast.

While black powders have many uses, their applications are limited because they disintegrate in water and therefore cannot be used in wet work except with special precautions.

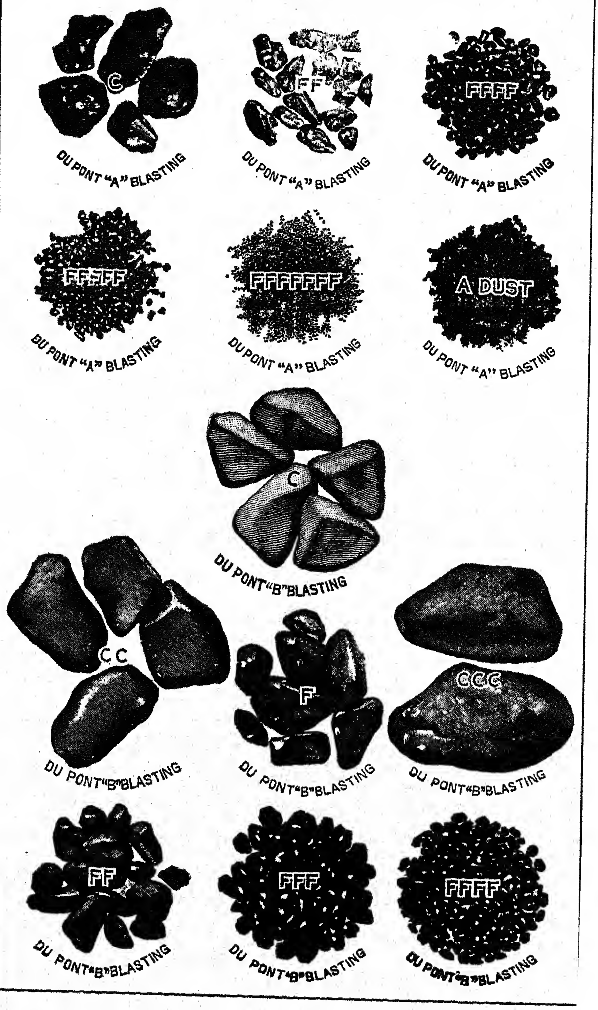
The most important use of black powders is in coal mining. They are superior to high explosives in this type of work because they have less tendency to shatter the coal and consequently produce less slack coal, better yields of prepared sizes, and more solid lumps. Black powders cannot be used, however, in coal mining where mine gas or dry coal dust is present in dangerous quantities. Under such conditions permissible dynamites should always be used.

Black powders are manufactured in two forms: black blasting powder and pellet powder.

BLACK BLASTING POWDER

The oldest and most widely known explosive is black blasting powder which is granulated black powder. It is a loose, free-flowing, definitely grained material normally packed in

FIG. 1—EXACT SIZE OF GRAINS OF DU PONT "A" and "B" BLASTING POWDERS



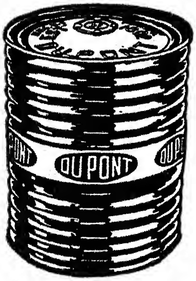


Fig. 2—25-lb keg of Du Pont Blasting Powder

bulk in metal kegs containing 25 lb of powder. The blasting powders generally used are glazed, this glaze being a high luster and polish applied to the surface of the grains by coating them with a small amount of graphite during the finishing process of manufacture after they are rounded, smoothed, and dried. This gives the powder a bright, attractive appearance, prevents it from caking together in the kegs during storage, and makes it free-running so that it will pack closely in the borehole. The glaze on blasting powder, however, does not increase its resistance to water or moisture when loaded in boreholes and does not improve its efficiency as a blasting agent.

Grades. Black blasting powders are manufactured in two grades: "A" Blasting Powder which contains saltpeter or potassium nitrate and "B" Blasting Powder which contains sodium nitrate instead of the potassium salt. In both powders the other ingredients are sulfur and charcoal. Because of the kind of nitrate used, "A" Blasting Powder is considerably faster, slightly stronger, and somewhat less hygroscopic than "B" Blasting Powder. "A" Blasting Powder, however, is much more expensive than the "B" grade and for that reason is very little used. Although "B" Blasting Powder is not so high in quality, it has a wide range of application and, because it is relatively cheap, it is widely used.

Granulations. The burning speed or rate of explosion of black blasting powders is controlled by the grain size—the finer the granulation, the faster the powder. Consequently, both the "A" and "B" grades are prepared in a variety of standard granulations. "A" Blasting Powder is available in eight standard granulations, CA to FFFFFFFA, inclusive, ranging from coarse to fine, respectively. "B" Blasting Powder is manufactured in seven standard granulations, CCC being the coarsest and FFFF the finest. The comparative sizes of the two series of granulations are illustrated in Fig. 1. In addition to the standard granulations, "B" Blasting Powder is also available in several special granulations which consist of mixtures of the standard sizes. The best-known special

granulation is RR or Railroad Powder which is a mixture of FF, FFF, and FFFF. It is an excellent granulation for many classes of blasting as it packs well in boreholes and explodes with great uniformity. A borehole of a given size will hold about 10% more pounds of the RR granulation than it will of any of the standard grain size. Consequently, the RR granulation will be found to be more effective for heavy blasting where charges exceed one keg (25 lb).

Uses. The chief applications of "A" Blasting Powder are in certain classes of difficult blasting, as in quarrying fine dimension stone, granite, and slate, where an explosive quicker than "B" Blasting Powder is required and dynamite is undesirable because of its shattering effect. A small amount of "A" Blasting Powder is also used in the manufacture of fireworks, fuse, and miner's squibs.

"B" Blasting Powder is used principally to shoot coal in underground mines that are non-gassy and in open stripping operations. It is also used in strip pits to blast the overburden where the ground consists of soft rock, shale, loam, or clay. Other uses include clay and shale mining, blasting side-hill cuts, and general excavating in light ground where a slow heaving action is desirable and where the work is dry. The applications of "B" Blasting Powder in quarrying are somewhat limited by the hardness of the rocks encountered but it is used to some extent in stone quarries especially where the material is desired in large, solid blocks for breakwaters and jetties.

PELLET POWDER

Pellet powder is an improved form of black powder. The name is derived from the fact that the powder is pressed into cylindrical pellets approximately 2 in. in length and varying in diameter from $1\frac{1}{8}$ to $2\frac{1}{2}$ in. Each pellet has a center hole $\frac{3}{8}$ in. in diameter to facilitate rapid and even ignition and to allow fuse to be laced through the cartridges or an electric squib to be inserted. Four of these pellets are wrapped in red shell paper to form a cartridge

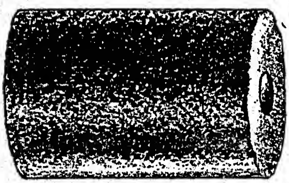


Fig. 3—A single pellet

8 in. in length. The cartridges are then dipped in paraffin and packed in wooden cases, with either 25 lb or 50 lb to the case.

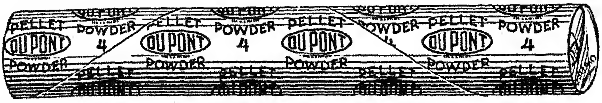


Fig. 4—Pellet powder cartridge

The composition of the pellet powders are basically the same as "B" Blasting Powder, modified slightly by the addition of various ingredients to control the physical and explosive properties of the respective grades.

Grades. Du Pont pellet powders are manufactured in five standard grades. They are graded according to type, density, and speed of explosion. There are two types of pellet powders: those pressed from a definitely grained and relatively high density powder, the No. 1, No. 2, and No. 3 grades; and those pressed from a heterogeneous mass of low density powder, the No. 4 and No. 5 grades.

Three density ranges are utilized: high density or low cartridge count—No. 2 and No. 3 grades; medium density—No. 1 grade; and low density or high cartridge count—No. 4 and No. 5 grades. The following table shows the cartridge counts for all grades in the various sizes:

TABLE I

Pellet Powder Grade	Cartridges per 50 lb*						
	1⅛ x 8″	1¼ x 8″	1⅜ x 8″	1½ x 8″	1¾ x 8″	2 x 8″	2½ x 8″
No. 1	144	114	90	76	54	41	28
No. 2	136	106	84	70	50	37	26
No. 3	136	106	84	70	50	37	26
No. 4	—	125	102	84	60	48	30
No. 5	—	125	102	84	60	48	30

* With an allowable variation of plus or minus 3%.

The grading on the basis of speed is shown by the following tabulation:

SPEED RANGE	GRADE
Fast	No. 1
Medium Fast	No. 4
Medium	No. 2
Medium Slow	No. 5
Slow	No. 3

Uses. Pellet powders are adaptable to most of the uses mentioned for "B" Blasting Powders. They are a cartridged product, however, primarily designed for blasting in boreholes of the smaller diameters, whereas the granular powders are bulk explosives used as well for heavy blasting. Pellet powders are slightly higher in cost than "B" Blasting Powder but this is offset by the convenience and overall greater efficiency they show in small, borehole-confined charges, as in shooting coal. They have no advantage over the blasting powders, however, in large charges such as well drill holes in overburden, sprung holes, and coyote tunnel blasts.

The principal use of pellet powders is in shooting coal (underground and stripped) and in blasting of a similar nature such as in clay mining. The properties of the various grades are discussed in the following paragraphs from the standpoint of their execution in coal.

Du Pont No. 1 Pellet Powder does excellent work in open friable coal where slower pellet powders have failed. Its pressure is developed so rapidly that the gases have less time to escape through the fissures in the coal. Consequently, it is possible to use this pellet in some non-gaseous and non-dusty mines where permissibles have previously been necessary and thereby secure both a better yield of coarse coal and a lower blasting cost.

Du Pont No. 2 Pellet Powder gives medium speed execution at high loading densities and has, therefore, a very wide range of application, rivaled only by the No. 4 grade.

Du Pont No. 3 Pellet Powder permits high loading densities and is very slow in action. It is particularly adapted for shooting off the solid in the mid-western coal fields. It has also proved excellent in these and other districts for shooting undercut, close, hard coal where the No. 2 grade is too fast. The slower powders are designed to produce more lump coal and fulfill this purpose wherever they can be used. They heave and shear slowly but effectively with a minimum shattering effect on the coal.

Du Pont No. 4 Pellet Powder supplies an excellent balance between speed and low density which adapts it to an exceptionally wide field. No. 4 Pellet Powder has been shot successfully against the higher density grades and can usually be substituted economically for Du Pont Pellet Powders No. 1 and No. 2. Its low density makes possible closer gauging of charges and this in turn is reflected in less shattering effect.

Du Pont No. 5 Pellet Powder is practically identical in composition and physical properties with the No. 4 grade. It is specially treated, however, to obtain a medium slow-burning speed and may be used wherever a slow powder is required, including such work as is particularly adaptable to the No. 3 grade. Having the same density and cartridge count as the No. 4 grade, it is a valuable substitute where the latter has proved too fast for general satisfaction but where stick count is an important factor. No. 5 Pellet Powder is excellently adapted to lump coal production—it is low in density and slow in action.

Advantages. Pellet powders are less dangerous to handle, more convenient to load, and more efficient and economical to use than granular powders.

The wrapper provides an appreciable protection for the powder from open flames. The wrapper and wooden cases in which the cartridges are packed also constitute a safe and non-conducting container which minimizes the hazards of transporting or handling powder in electrified mines and of the careless usage of metal tools for opening containers, all recognized hazards associated with granular powders in metal kegs.

The wrapper effectively protects the powder from moderate exposure to dampness. Because of this, full strength and proper speed of the powder are preserved over reasonable periods of storage, and the powder can be used in moderately wet work.

The convenience of using pellet powders is obvious—the necessity of making up, filling, and waterproofing cartridges is eliminated and charges may be more accurately gauged.

Added economy in the use of pellet powders results from this ability to gauge loads accurately. Each cartridge of a particular grade and size is uniformly the same in weight. The cartridges are divisible into fourths which provide a sufficiently small variable in adjusting charges. There is little waste or danger from spillage.

Pellet powders are frequently more efficient in certain types of coal than granular powders. Normally, pellet powders should be loaded against granular powder on a weight-for-weight basis. In many seams of coal, however, the ratio of pellet to granular may be considerably reduced, resulting in lower powder costs and the production of better coal.

SMOKE AND FUMES FROM BLACK POWDER

Black powders, in common with all other explosives, produce varying amounts of smoke and gases when they explode. Smoke consists of the visible, air-borne products of explosion, while the gases are the invisible products. Smoke and most of the gases are practically harmless but a small proportion of the gases is poisonous. The poisonous gases are referred to as fumes. In the case of black powder, the fumes are carbon monoxide and hydrogen sulfide.

Characteristics. Black powders tend to produce more smoke and fumes than most dynamites. Smoke is objectionable primarily from the standpoint of reducing visibility in an enclosed place immediately after the blast. The amount of smoke produced is variable and there is no consistent relationship between it and fumes.

Determining Factors. Fume formation in the case of black powders is unique in that the quantity and composition of the poisonous gases produced are less a function of the composition of the powders and more a function of the conditions under which they are exploded. All black powders have essentially similar compositions and have potentially similar gaseous products of explosion, but the fumes they actually do produce are so much influenced by speed of explosion, degree of confinement, and other factors that wide variations and inconsistencies are possible. It may be assumed that the fumes are always poor, but two powders of similar composition (but of different speeds, for example) exploded under identical conditions or the same powder exploded under different conditions may produce radically different fumes.

There is one general rule, however, that applies in the case of black powders—*as the grade of powder used and the manner in which it is used give greater all-around blasting efficiency, smoke and fumes are less obnoxious.* Blasting efficiency is greater as the grade of powder used is better adapted to the material being blasted and as greater care is utilized in drill-

ing, loading, and tamping practices. Some of the more important causes of excessive smoke and fumes are the use of a grade that is too fast or too slow; overloading or underloading; burdens that are too heavy or too light; blown-out shots from insufficient tamping or from boreholes that are too tight; and wet holes.

It has been mentioned previously that pellet powders can be loaded more accurately than "B" Blasting Powder and function with greater efficiency in many types of coal. Because of this they have an added advantage that they frequently produce less smoke than the blasting powder. It should be emphasized, however, that *pellet powder and black blasting powder are approximately the same in composition and, therefore, the harmful gases to be expected are essentially the same pound for pound; but more important still—improper selection of grades or improper use can definitely increase the hazard with either. When using either of these powders, therefore, men should be warned not to return to the face too soon after blasting.*

CHAPTER II

DYNAMITE

High explosives include all explosives which decompose by detonation. Detonation is an extremely rapid, almost instantaneous, process; hence, the action of high explosives is fast and violent, accompanied by shattering effect.

Commercial high explosives are more familiarly referred to as dynamites. There are several types of dynamites in common use and each type is further subdivided into a series of grades. Each type and each grade is different from any other in one or more characteristics. The various characteristics of an explosive are known as its properties.

In selecting high explosives for any specific purpose and especially for underground work, many factors must be taken into account. The more important external considerations involve the material to be blasted—its denseness, hardness, toughness, friability, etc.; the degree of fragmentation desired; whether the holes be wet or dry; the amount of ventilation in underground working places; and whether or not combustible gases or dusts are present. Each blast presents some combination of such conditions and each condition is associated with some property of high explosives. Hence, a dynamite with the proper combination of properties should be chosen. Some of the principal properties are strength, velocity, water resistance, density or weight per cartridge, fumes as products of detonation, and permissibility which involves the duration, temperature, and amount of flame.

PROPERTIES AND THEIR SIGNIFICANCE

Strength. The term "strength" refers to the energy content of an explosive which in turn determines the force and power it develops and the work it is capable of doing.

The straight dynamites are rated in strength according to the percentage by weight of nitroglycerin which they contain, that is, a 40% straight dynamite actually contains 40% of nitroglycerin by weight. An erroneous concept is that the actual blasting power developed by different strengths is in direct proportion to the percent markings; for example, that

40% dynamite is twice as strong as 20%, and that 60% is three times as strong as 20%. Such simple ratios do not exist, however, because the nitroglycerin is not the only energy-producing ingredient in straight dynamites. A 20% straight dynamite contains 20% of nitroglycerin and 80% of other ingredients which contribute to the total energy delivered by the explosive. When the percentage of nitroglycerin is increased to 60%, the energy obtained from the nitroglycerin alone is trebled, but that contributed by the remaining ingredients is reduced in the ratio of 80 to 40. Consequently, the energy gained by increasing the nitroglycerin is partially lost by the necessary decrease in other ingredients, and a 60% straight dynamite, rather than being three times as strong as a 20%, is actually only one and one-half times as strong.

In other types of dynamites the proportion of nitroglycerin is reduced and other strength imparting ingredients, such as ammonium nitrate, are substituted. By this means it is possible to produce a variety of dynamites equaling the various grade strengths of straight dynamite on a weight-for-weight basis; for example, one pound of "Red Cross Extra" 40% has the same strength as one pound of Du Pont Straight Dynamite 40%, in spite of the fact that the former contains much less than 40% of nitroglycerin. The percent strength markings for both of these grades are weight-strength markings which are the ones most commonly used in referring to dynamite.

Dynamites are sometimes also graded according to their bulk or volume strength. This refers to the strength per cartridge of the explosive, and the bulk-strength figure indicates that one cartridge of the dynamite, so marked, has a strength comparable with one cartridge of straight dynamite of the same percentage and size.

It should be pointed out, however, that two dynamites of the same strength do not necessarily produce the same blasting action. This is due to the fact that properties other than strength, particularly density and velocity, influence performance.

Density. The exact definition of "density" is the weight of a material per unit of volume. In the case of high explosives, density is conveniently expressed in terms of the number of 1¼"x 8" cartridges contained in a 50-lb case. In the present line of du Pont explosives this varies from 83 for Du Pont Gelatin 20%, to 250 cartridges per 50 lb for "Duobel" G.

The purpose of density variations in explosives is to enable the blaster to concentrate or distribute charges at will. In

many cases, such as in mining hard ore and driving tunnels through hard rock, it is necessary to use dense, low count powders in order to break the burden. In other cases, as for example in producing lump coal, it is frequently advantageous to string out the charge with low density grades. In still other instances, as in quarrying, a high density explosive is sometimes used in the bottom of the hole and a bulkier one above in order to bring the charge up high enough in the hole to break the top rock without overloading.

Velocity. Velocity is a measure in feet per second of the speed at which the detonation wave travels through a column of an explosive.

The velocity of detonation is an indication of the speed of action of an explosive. As the velocity is increased, the explosive detonates more quickly and with greater shattering effect. Strength and density also have some influence on shattering action so that all three properties should be considered in the final selection of an explosive when fragmentation is important.

Water Resistance. This property, of course, refers to the ability of dynamites to resist the effects of water, and high explosives differ widely in their capacity to do this. The gelatin dynamites are practically waterproof. Some of the higher density ammonia dynamites possess good water resistance, while the low density ammonia dynamites and the permissibles have little or no water resistance. Dynamites which are penetrated by water first have their efficiency impaired and then, on prolonged exposure, may be desensitized to a point that they will not detonate. When water is encountered in blasting, therefore, an explosive with at least some water resistance is necessary. If the blasts are to be fired soon after loading, an explosive possessing medium resistance may be satisfactory, but if the explosive is to be left under water for any length of time, a water resistant one, such as gelatin dynamite, should be used. Obviously in dry work this property of explosives is of no importance.

Freezing Resistance. All du Pont high explosives are low-freezing. They will not freeze under ordinary exposure to such atmospheric temperatures as are normally met with in this country. This is an important property of explosives for it makes blasting possible in cold weather without the necessity for the hazardous process of thawing frozen explosives.

Fumes. The gases resulting from the explosion of dynamite are principally carbon dioxide, nitrogen, and steam, and these are, in the ordinary sense, nontoxic. In addition, there are three possible poisonous gases, namely, carbon monoxide, nitrogen oxides, and hydrogen sulfide, which in the explosives industry are called "fumes" from dynamite. Of these toxic gases, carbon monoxide is always present to some extent. Nitrogen oxides may sometimes occur in harmful quantities, usually due to improper use of the explosive, and hydrogen sulfide may be encountered under very exceptional conditions.

The fumes produced depend primarily on the composition of the explosive. Both the nature and the total quantity of the poisonous gases vary among the different types and grades of dynamite, but both of these factors can be controlled within certain limits through proper formulation. These factors are influenced to some degree by the conditions under which the explosive is used, but not to the extent to which conditions of use affect the fumes from black powder. For these reasons, dynamites can be classified according to their inherent fume characteristics, and two classifications used in the explosives industry are set forth and discussed in the appendix of this book.

For work in the open, the fumes from explosives are usually not significant but for underground work a dynamite which produces large amounts of poisonous gases should not be used, and usually one producing a minimum of fumes should be selected. There is no such thing as a "fumeless" explosive and the possibility of developing one appears extremely remote. For these reasons, ventilation, either natural or artificial, is absolutely essential in underground blasting. In fact, proper control of the atmospheric conditions underground is more important than the selection of the explosive.

GRADES AND THEIR PROPERTIES

Straight Dynamite. As previously stated, the percentage strength of a straight dynamite refers to the actual percentage by weight of nitroglycerin it contains. Du Pont Straight Dynamite is manufactured in a series of grades, with strengths varying from 15% to 60%. The principal characteristic of straight dynamite is its high velocity, which imparts a quick, shattering action. It resists water very well, particularly in the higher strengths. Its poor fumes, however, make it unsuitable for use underground or in confined spaces. Straight dynamite is a most efficient explosive for mudcapping boulders, scrapping old machinery, demolishing boilers and ships and objects under water.

Du Pont Ditching Dynamite. This is the name under which Du Pont Straight Dynamite 50% is marketed for ditching purposes. Special precautions are taken in the manufacture of this product in order to adapt it for ditch blasting by the propagation method. It can be relied upon to detonate from charge to charge with full force at all times and, therefore, it gives most uniform results.

Du Pont Submarine Dynamite. For submarine blasting, Du Pont Straight Dynamite 60% is cartridged in a special wrapper. This product is used where propagation from hole to hole is desired in submarine work and it has had an excellent record of performance.

"Red Cross Extra" Dynamite. This is an ammonia dynamite manufactured in a series of grades with strengths ranging from 15% to 60%, and all with cartridge counts of 110, 1¼"x 8", cartridges per 50-lb case. The "Red Cross Extra" dynamites do not have as high velocity as the straight dynamites, which is an advantage where less fragmentation is desired, but a disadvantage where high shattering action is needed. Although they do not possess as much water resistance as the straight dynamites, this property has been improved recently and they can now be used successfully in very wet work. However, these grades should not be used under water without wrappers. As a whole, they have better fumes than the straights and are, therefore, used underground where the ventilation is good, but they are not recommended for this work generally. They are also less inflammable and less sensitive to shock and friction than the straight dynamites.

The "Red Cross Extra" dynamites are probably the best-known all-around explosives. They are widely used in agricultural work such as stump and boulder blasting. They are also well adapted to general construction work and quarrying where the rock is not too hard.

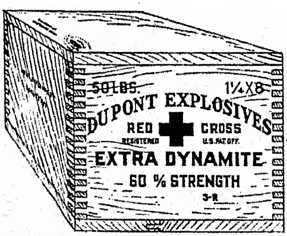


Fig. 5 —A case of "Red Cross Extra" Dynamite

Du Pont "Extra" Dynamite. The du Pont Company markets two series of high weight strength, low density ammonia dynamites under

the brand name Du Pont "Extra." In the first series there are eight different densities designated by the letters A to H, and in the second series, five densities designated by the letters C-1 to G-1. The second series differs from the first in that it has a lower velocity of detonation, each strength being approximately 3,000 feet per second slower than the corresponding strength of the first series. The following table shows the cartridge count and bulk strength of each grade:

TABLE II

Cartridge Counts and Bulk Strengths of Du Pont "Extra" Grades

High Velocity Series			Low Velocity Series		
Grade	Ctgs./50 lb 1¼"x 8"	Bulk Strength	Grade	Ctgs./50 lb 1¼"x 8"	Bulk Strength
A	115	55%			
B	120	50%			
C	128	45%	C-1	128	45%
D	135	40%	D-1	135	40%
E	142	35%	E-1	142	35%
F	152	30%	F-1	152	30%
G	162	25%	G-1	162	25%
H	172	20%			

The Du Pont "Extra" dynamites tend to absorb moisture quickly and for that reason require a good protective wrapping or careful attention to conditions during storage. They are available in two types of wrappers, the standard which is paraffin-coated to provide maximum protection, and a special which is uncoated to minimize fumes. The standard wrapper is recommended for damp or prolonged storage. Where fumes are important, however, and the storage is dry or of short duration, the special uncoated wrapper is preferable.

Du Pont "Extra" A, B, C, and D have considerable water resistance, though not as much as the "Red Cross Extra"

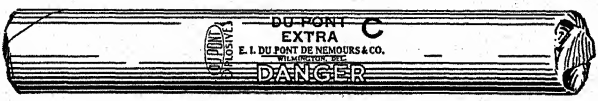


Fig. 6—A cartridge of Du Pont "Extra" Dynamite

grades, but the remaining grades of the high velocity series, and all of the low velocity grades of the Du Pont "Extra" series have little or no water resistance. When packed in standard wrappers all of the Du Pont "Extra" grades have fair fumes, but as indicated previously, in special wrappers their fumes are better and, in fact, good in the case of the higher bulk strength grades. Both high and low velocity Du Pont "Extra" grades have very low inflammability.

Du Pont "Extra" dynamites have proved very efficient and economical for two different purposes in quarrying: as a top load in well drill holes; and as a block hole charge for secondary blasting, especially where it is desirable to avoid fines. For these quarry uses, the high velocity grades are usually best adapted. Du Pont "Extra" dynamites are also well suited to mining soft ore, limestone, gypsum, salt, clay, and similar materials, and almost invariably prove the most economical explosive for this class of work. While the high velocity Du Pont "Extra" grades have given excellent results and are still used with entire satisfaction in such mines, in some cases the low velocity grades have been found better adapted. Examples of this are in limestone and salt mines where the lower velocity explosives throw the material farther back from the face so that two or three more shots can be blasted before it is necessary to bring in the shovel.

"Red Cross" Blasting FR Dynamite. This comprises a series of grades including No. 2, No. 3, No. 4, and No. 5, having 25%, 30%, 40%, and 65% strengths, respectively. These dynamites are characterized by their extremely good free running qualities. They are usually packed in 12½-lb bags, four bags to the 50-lb case. They are designed primarily for loading into small diameter drill holes which have been chambered at the bottom, and holes that are too ragged for satisfactory loading with cartridges. The "Red Cross" Blasting Free Running grades have essentially no water resistance but they may be regularly used where the work is a little too wet for black powder. They have poor fumes and hence should not be used in other than open work.

The "Red Cross" Blasting Free Running grades may be detonated by means of "Primacord" but the most economical and general method is by means of a dynamite primer of at least 40% strength. Usually one cartridge, 1¼″x 8″ size, is used for each charge. Priming by a blasting cap or an electric blasting cap is not recommended.

These dynamites have been used extensively to replace black blasting powder. They not only have the advantage of freeing the work of the spark hazard always present when black powder is used, but they are also frequently more economical. Field experience shows that 60 to 75 lb of "Red Cross" Blasting FR powder (according to grade) will replace 100 lb of black powder.

Fig. 7—"Red Cross" Blasting Free Running Dynamite

Because of the free running and low velocity characteristics of these grades, they are particularly well suited to the production of riprap. For this work they can be poured into small diameter drill holes, either sprung or not sprung, and they may be stacked in bags in coyote tunnels. These grades are also used in well drill holes in quarries where it is desirable to fill the boreholes completely or where a low velocity explosive is essential. In the latter case, these grades are sometimes used in regular dynamite cartridge form.

"Agritol." This is an explosive of the low-density ammonia type developed for certain kinds of agricultural work. It has a cartridge count of 172, 1¼"x 8", cartridges per 50-lb case, which means that it is an economical explosive to use where adapted. Due to its high cartridge count, however, the cartridges will float in water and, therefore, it is best suited for dry work. It gives excellent results in subsoil blasting and for blasting dead stumps.

"Agritol" No. 2. This explosive was developed because of a demand for a general-purpose agricultural explosive suitable for all blasting work on farms other than ditch blasting. It is designed so that each cartridge will sink in water, having a count of 132, 1¼"x 8", cartridges per 50-lb case. It will shoot green or dead stumps and is excellent for breaking boulders. It is not as good as "Agritol" for subsoil blasting on a cost basis, but will give good results. It is an excellent all-purpose dynamite.

Southern Stumping. The southern yellow pine and related trees all have tap roots, and the blasting of their stumps presents a special problem. Experience has led to the development of Southern Stumping dynamite for this purpose. It is fast enough to cut off the tap root and dense enough to require a small diameter drill hole. It runs 120 cartridges, 1¼"x 8", per 50-lb case. It keeps well in hot, damp locations. It is an excellent dynamite for breaking boulders but it is not recommended for ditch blasting nor for subsoil blasting.

Gypsum A. As stated previously, the low velocity Du Pont "Extra" dynamites have proved very satisfactory for blasting in gypsum and salt mines. However, some of these mines present a special problem, and a modification of Du Pont "Extra" F-1, marketed under the name of Gypsum A, has been developed for this work. Improved fumes characterize this grade.

Du Pont Gelatin. The explosive base of gelatin dynamite is a jelly made by dissolving nitrocotton in nitroglycerin. Gelatinized nitroglycerin may vary in consistency from a thick, viscous fluid to a tough, rubber-like substance; it is insoluble in water and tends to waterproof other materials which it coats or encloses. A series of grades containing nitrocotton and nitroglycerin as the only explosive ingredients, and varying in strength from 20% to 90%, is marketed under the name of Du Pont Gelatin. These explosives are dense, plastic, cohesive, and practically waterproof. They have excellent fumes in the 20% to 60% grades, inclusive, but in the higher strengths their fumes are poor. Their plasticity makes it possible to load them solidly in boreholes with a minimum loss of effect due to air space in the charge. When well confined they develop high velocity of detonation and consequently a quick, shattering action. These two characteristics, combined with their high density, make them most effective in hard, tight work and in operations where a maximum shattering effect is desired. Du Pont Gelatin is adapted to all varieties of wet work. It is recommended especially for tunnel driving in very hard rock and it is the best type of explosive for loading in uppers such as are commonly used in stopes since it sticks well in these boreholes. Du Pont Gelatin does not enjoy wide use at the present time, however, because of its high cost in comparison with other grades which can be substituted perfectly satisfactorily for most work.

"Hi-Velocity" Gelatin. It is an inherent property of gelatin dynamites to detonate at two velocities. Primed with a No. 6 cap and shot unconfined, they will usually explode at a rate of approximately 7,000 feet per second, while they explode at a higher rate of 13,000 to 22,000 feet per second, according to strength, when shot confined or with a straight dynamite primer. Frequently under submarine blasting conditions, a straight dynamite primer is not sufficient to insure high velocity and burned holes and sub-standard execution may result. This is especially true when gelatin dynamites are used under high water pressures.

A series of straight gelatins from 50% to 90% strength, which always detonate at high velocity, even when shot unconfined with a No. 6 cap, was therefore developed and is sold under the name of "Hi-Velocity" Gelatin. Actually their velocity of detonation is the same as the high rate for the corresponding grades of Du Pont Gelatin. They are lower in density than the regular Du Pont Gelatins, averaging about 10% more cartridges per case, and they have the same weight strength, grade for grade, as the standard type, but correspondingly lower bulk strengths due to their lower density. They are nearly twice as sensitive to detonation as regular Du Pont Gelatins, but no more sensitive to shock or friction. The "Hi-Velocity" Gelatin grades have excellent water resistance but have poor fumes and, therefore, should not be used in underground work.

This property of attaining high velocity under all conditions and without the use of a straight dynamite primer is of distinct value in submarine blasting and oil and gas well shooting where the explosive is usually under considerable pressure. "Hi-Velocity" Gelatin dynamites are recommended for submarine work and are particularly adapted where propagation from hole to hole is undesirable.

Blasting Gelatin. This is the strongest (100%) and highest velocity commercial explosive in existence. It can be handled, transported, and used as safely as any high explosive. Instead of being plastic, it has a texture like para rubber. It is absolutely waterproof. It is adapted for some special cases of tunnel driving, shaft sinking, deep well shooting, and submarine work. Its fumes are poor, and when unusual rock conditions necessitate its use underground or in confined spaces. great care must be exercised to insure adequate ventilation,

TABLE III

Properties of Dynamites other than Permissibles

GRADE	STRENGTH		DENSITY Ctgs per 50 lb 1¼" x 8" (1)	VELOCITY Ft per Sec	WATER RESISTANCE	FUMES (2)
	Weight	Bulk				
Du Pont Straight	15–35% 40–50% 60%	15–35% 40–50% 60%	102 102–104 106	8,200–12,800 13,800–16,100 18,200	Poor Good Excellent	Fair Very Poor Very Poor
"Red Cross Extra"	15–35% 40–60%	11–29% 35–55%	110 110	7,400– 9,600 10,400–12,800	Fair Good	Fair Fair
Du Pont "Extra"	A to D E to H C-1 to G-1	55–40% 35–20% 45–25%	115–135 142–172 128–162	10,800– 9,500 9,300– 8,800 7.700– 6,500	Fair Poor Poor	Good (3) Good (3) Good (3)
Du Pont Gelatin	20–60% 75–90%	30–59% 67–79%	85–96 101–107	10.500–19,700 (4) 20,600–22,300 (4)	Excellent Excellent	Excellent Very Poor
"Hi-Velocity" Gelatin	50–80%	41–56%	100–120	18,000–21,600	Excellent	Very Poor
Blasting Gelatin	100%	100%	110	23,600	Excellent	Poor
Special Gelatin	30–80% 90%	35–70% 79%	88–107 109	13,100–17,100 (4) 19,700 (4)	Excellent Excellent	Excellent Poor
Seismograph Gelatins	60%	48–55%	100–107	17,100 (4)–19,700	Excellent	Very Poor
"Gelex"	No. 1 & No. 2	60 & 45%	110–122	14,100–12,600	Very Good	Excellent

NOTES: (1) Subject to a variation of plus or minus 3% from standard
(2) Grades rated with "Very Poor" fumes are not recommended for underground use.
(3) This fume rating for the du Pont "Extra" dynamites applies only to special wrappers; in standard wrappers the fume rating is "Fair."
(4) The velocities shown for these gelatin dynamites are the high values developed when detonated unconfined with a straight dynamite primer.

Special Gelatin. The Special Gelatin dynamites comprise a series which correspond to the "Extra" dynamites in the non-gelatinous group in that part of the nitroglycerin is replaced by ammonium nitrate. They are the equal of the Du Pont Gelatins in all respects except that they are somewhat lower in velocity and slightly less water resistant; but they are so water resistant that they are commonly loaded in water-filled holes, either with or without wrapper, and fired with little or no loss of efficiency after standing several days. They have excellent fumes in the 30% to 80% grades and fair fumes in the 90% grade.

Special Gelatins have been substituted for Du Pont Gelatins in all classes of work except submarine blasting and blasting in extremely hard rock. They are more economical to use than the Du Pont Gelatins.

Gelatin dynamites cannot be recommended for mudcapping unqualifiedly because they tend to detonate at low velocity when unconfined, and consequently with a relatively slow, non-shattering action. Nevertheless, their plasticity makes them so easy to apply to irregularly shaped objects that many blasters prefer them to the more efficient but crumbly explosives.

Seismograph Gelatins. Two grades of gelatins are manufactured especially for seismic prospecting. The first, marketed under the name of Seismograph "Hi-Velocity" Gelatin 60%, is a modification of regular "Hi-Velocity" Gelatin 60% incorporating all the advantages of that grade but, in addition, having a rigid cartridge which makes it particularly adapted for this type of work. The other grade is a modification of Special Gelatin 60% having extra stiffness and cartridged in the same manner. The "Hi-Velocity" grade is intended for use in particularly deep holes where exceptional water resistance and ability to detonate completely and at high velocity under high water pressures are required.

"Gelex." Two semi-gelatin dynamites combining the economy of the low density Du Pont "Extra" Dynamites with water resistance and cohesiveness imparted by gelatinized nitroglycerin are marketed under the names of "Gelex" No. 1 and "Gelex" No. 2. These are high weight strength grades. Their cartridge counts are 110 and 122, 1¼"x 8", cartridges per 50 lb, and their bulk strengths 60% and 45%, respectively. Their velocities and water resistances are somewhat lower than the corresponding bulk strength Special Gelatins, but are adequate

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for most purposes. Unlike the gelatins, they always detonate at their characteristic velocity even when fired unconfined.

Fig. 8—A case of "Gelex" No 2

The "Gelex" grades are used in under-water holes in quarries without wrapper, but this practice is not recommended for operations where there is liable to be a long delay between loading and firing, because the efficiency of these grades is gradually impaired after several hours' exposure to these conditions. They are cohesive enough to load well in uppers, their fumes are excellent, and they are less inflammable than gelatins.

The "Gelex" grades are doing excellent work in quarrying, metal mining, limestone and gypsum mining, and tunneling. For this work "Gelex" No. 1 has replaced 50% and 60% gelatin in many instances, and "Gelex" No. 2 has proved exceedingly effective as a replacement for 30% to 40% gelatins. Wherever applicable, the "Gelex" grades give lower costs than the gelatin dynamites. They are not recommended for submarine work nor for shooting wells.

Permissibles. Permissible dynamites are explosives which have been tested by the United States Bureau of Mines and passed as safe for blasting in gaseous and dusty mines if used in accordance with certain specified conditions. The most important of these requirements of permissible usage are that the explosive shall be in all respects similar to the sample submitted by the manufacturer for test (which means principally that it shall not have been allowed to deteriorate in storage); that it shall be fired with an electric detonator of strength not less than a No. 6 detonator whose charge consists by weight of 80 parts of mercury fulminate and 20 parts of potassium chlorate (or their equivalents), and that this electric firing shall be done by means of a permissible type blasting

unit; that the quantity used for a shot shall not exceed 1½ lb; that the charge shall be properly confined in a borehole tamped with clay or other non-combustible stemming; and that the charge is not fired in the presence of gas.

All explosives when fired give a flash or flame which varies in length, duration, and temperature. Black blasting powder gives the largest and longest lasting flame. Dynamites of various kinds give a flame which is not as large and does not last as long as that of blasting powder but which is very much hotter. Permissible explosives are especially designed to give such a small flame and of such brief duration and low temperature that, if they are used in accordance with the prescribed conditions, there is very little likelihood of the ignition of gas or dust taking place.

Du Pont permissibles comprise three series of non-gelatinous ammonia permissibles: (1) high velocity grades or the "Duobel" series; (2) low velocity grades or the "Monobel" series; and (3) very low velocity grades or the "Lump Coal" powders. In addition there is a series of gelatinous permissibles known as the "Gelobel" grades.

Permissible explosives, particularly the low and very low velocity grades, absorb moisture readily and deteriorate as a result. As stated above, permissibles which have deteriorated are not permissible for use. In view of these facts, careful consideration should be given to the storage of these grades. First, good conditions of storage should be provided; and second, stocks consistent with needs should be purchased and old stocks used first so that the length of the storage period is not unduly prolonged.

The high velocity permissibles comprise the following in the order of their increasing stick count: "Duobel" A, B, C, D, E, F, and G. These comprise a complete series of cartridge counts from 135 to 250, 1¼"x 8", cartridges per 50 lb. "Duobel" A, B, and C are strong, fast explosives suitable for thick coal with heavy binders of impurities. They are applicable where high tonnage per pound of explosive is desired and lump coal is not a factor. They can also be used successfully in medium hard rock shooting met in some coal mines. In addition, they have considerable water resistance and hence can be used in certain operations formerly requiring gelatinous permissibles, as for example, in top cut coal where the bottom holes are under water. "Duobel" D, E, F, and G, particularly the latter two, are bulky explosives which were developed primarily for thin coal seams with deep cuts where the explosive charges

must be strung out to pull the entire depth of such cuts and where air spacing or cushion blasting is prohibited. They produce a very good grade of coal and at a minimum of cost to users. For the most part, all of the "Duobels" are used in 1¼" diameter.

The low velocity permissibles comprise the following in the order of increasing cartridge counts from 135 to 205, 1¼"x 8" cartridges per 50 lb: "Monobel" A, B, C, D, and E. On the whole, these grades are used in operations where coarse coal is a factor since they produce higher percentages of the large sizes than the "Duobel" powders. Generally speaking, "Monobel" A and B are used in thick coal seams, "Monobel" C and D in seams of medium thickness, and "Monobel" E in thin veins. In hand loading mines where miners drill the holes, the 1¼" diameter cartridge is usually used, whereas in mechanical mines larger diameters are preferred. The use of these larger diameter cartridges in the back of drill holes often helps to improve the percentage of coarse coal, and is effective

Fig. 9—A cartridge of "Monobel" C

in throwing the coal from the face so that loading machines can operate at high efficiency. It should be mentioned here that "Monobel" C is the most widely used of any permissible on the United States Bureau of Mines Active List.

There are two very low velocity permissibles, "Lump Coal" C and "Lump Coal" CC each with a density corresponding to 165, 1¼"x 8", cartridges per 50 lb. The latter is sold in the 1¼" diameter but the former is sold in diameters of 1½" and greater only. "Lump Coal" C is a strong, very slow explosive with less shattering effect than other permissibles. It has a wide spreading range and in many cases can be shot more economically than other permissibles due to the fact that a smaller number of holes is required. It has essentially no water resistance but this does not prevent its use in damp holes where precautions are taken to guard against water entering the cartridge. Its fumes are of the best, which is an important factor in mechanical loading. "Lump Coal" C performs more

TABLE IV

Properties of Permissible Dynamites

Grade	Cartridges per 50 lb 1¼"x 8" (a)	Velocity feet per second (b)	Fume Class (c)	Cartridges per 1½ lb 1¼"x 8" (d)
"Duobel" A......	135	9,200	A	4.1
"Duobel" B......	150	9,000	A	4.5
"Duobel" C......	165	8,800	A	5.0
"Duobel" D......	185	8,400	A	5.6
"Duobel" E......	205	8,000	A	6.2
"Duobel" F......	225	7,400	B	6.8
"Duobel" G......	250	7,100	B	7.5
"Monobel" A.....	135	7,000	A	4.1
"Monobel" B.....	150	6,400	A	4.5
"Monobel" C.....	165	6,200	A	5.0
"Monobel" D	185	6,100	B	5.6
"Monobel" E.....	205	6,000	B	6.2
"Lump Coal" C...	118 (e)	5,000	A	3.5 (e)
"Lump Coal" CC .	165	5,500	A	5.0
"Gelobel" A......	96	14,000	A	2.9
"Gelobel" B......	108	11,500	A	3.2
"Gelobel" C......	120	11,500	A	3.6

(a) 3% allowable variation. (b) unconfined. (c) Bureau of Mines data. (d) charge limit. (e) not made in less than 1½" diameter 118 cartridges 1½"x 8"; 115 cartridges 1¾"x 6"

nearly comparable to black blasting or pellet powder than any other permissible. Lumps are larger and firmer and stand up better in transportation and handling. In view of all these qualities, this grade is especially adapted for mechanical loading in thick coal seams where lump coal is desired. "Lump Coal" CC approaches "Lump Coal" C in performance but was designed primarily for coal mines where hand drilling is employed and hence where the drilling of the coal for larger diameter cartridges is a burden.

There are three gelatinous permissibles, "Gelobel" A, B, and C, the former being a true gelatin with a cartridge count of 96, 1¼″x 8″, cartridges per 50 lb and the latter two semi-gelatinous explosives with cartridge counts of 108 and 120, 1¼″x 8″, cartridges per 50 lb respectively. The "Gelobel" grades were originally designed for rock work in coal mines, but are now commonly used for blasting coal where the work is wet. Because of their high velocity, they do not produce as high a percentage of coarse coal as the non-gelatinous grades, but at the same time do give a very good grade of coal. They are customarily used in the 1¼″x 8″ size. "Gelobel" B and C are higher weight strength explosives than "Gelobel" A and, therefore, more economical where adapted.

CHAPTER III

"NITRAMON"

The du Pont Company developed for several purposes a blasting agent which it sells under the trademarked name of "Nitramon." "Nitramon" consists of a mixture of materials, including ammonium nitrate, which is packed in metal cans. It differs radically in both properties and appearance from any material used for blasting heretofore.

Among the numerous advantages of "Nitramon," the safety of handling and use is probably the most important. It is not an explosive in the accepted sense of the word since it cannot be detonated by (1) the strongest of commercial blasting caps; (2) Primacord; (3) flame; or (4) the impact of a rifle bullet or of heavy steel weights such as drill bits. Its full blasting strength is developed, however, by the use of a suitable primer. As a primer, a special type containing T.N.T. in combination with other materials is strongly recommended.

Other important advantages may be briefly stated as follows: (1) "Nitramon" is packed in tightly sealed metallic containers and, as a result, its water resistance is unlimited provided the cans are properly handled and loaded; (2) it is non-headache producing, not only because of the nature of its package but also due to the fact that it contains no nitroglycerin; (3) it is absolutely non-freezing; and (4) it shows appreciable savings to the purchaser in many cases.

There are two types of "Nitramon," the first intended for large diameter drill holes in quarries and open pits, and the second designed for small diameter drill holes and more especially for seismic prospecting.

LARGE DIAMETER "NITRAMON"

Grades. "Nitramon" in four-inch diameter and larger cans is offered to the trade in five grades, designated as "Nitramon" A, B, C, D, and No. 2. The alphabetical grades all possess the same high strength per unit of weight. They differ only in density, that is, in bulk strength or in strength per foot of borehole occupied. Grade A, with the strongest bulk, compares to 75% gelatin; Grade D, with the weakest bulk, com-

pares to 40% ammonia dynamite; and Grades B and C fill in a logical series of strengths intermediate between A and D. "Nitramon" No. 2 has both a weight and bulk strength of approximately 40%, and a density corresponding to Grade B. The sizes available in each grade are shown in the accompanying table. It will be noted that these sizes cover the range of borehole diameters commonly encountered in present-day well drill blasting.

TABLE V

Number of Standard Size Cans per 1,000 Pounds

"Nitramon"

Can Size	Grade A	Grade B	Grade C	Grade D	No. 2
4" x 24"	—	72	78	94	72
4½" x 24"	53	59	64	78	59
5" x 24"	43	48	52	64	48
5½" x 24"	36	40	45	55	40
6" x 24"	30	33	36	43	33
7" x 24"	23	—	28	34	24
7½" x 24"	19	—	23	29	20
8" x 21"	19	—	23	—	20
9" x 19"	19	—	23	—	20

The cans of "Nitramon" A, B, and No. 2 are of such weight that they sink readily in water, while those of Grade C are only slightly heavier than water. Ordinarily, therefore, these grades are preferred for blasting under water. The cans of Grade D are lighter than water so that these are primarily for use in dry work or above water level. The velocity of detonation of "Nitramon," like that of explosives, varies with the grade and diameter. On the average the velocity of the alphabetical grades is approximately 16,000 feet per second, and the No. 2 grade, approximately 10,000 feet per second. It will be recognized that these are comparable to the velocity of many explosives used in well drill holes.

"Nitramon" has proved satisfactory for numerous types of rock in quarry work, notably, shale, limestone, cement rock, trap rock, and granite. It is also used in open pits for stripping overburden and for blasting iron ore. "Nitramon" was devel-

oped primarily for well drill hole blasting, but it is also a very desirable blasting agent for coyote tunnels because of its safety and non-headache features. It should not be used in sprung holes.

The amount, grade, and size of "Nitramon" to use must be determined accurately for each operation. A survey to establish this information should be made by an experienced person.

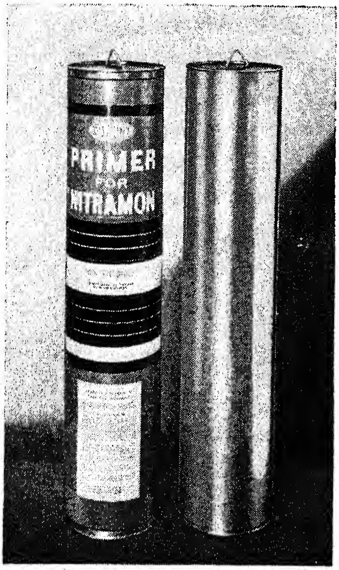


Fig. 10—A "Nitramon" primer and a can of "Nitramon"

Primers. As indicated previously, special primers have been developed for "Nitramon." These are made in three sizes, namely, 4, 5, and 7 inches in diameter.

The type of "Nitramon" primer for electric blasting caps has 6 inches of amatol (T.N.T. and ammonium nitrate) at the top of the can and 18 inches of "Nitramon" in the bottom of the can. The caps are placed in tubes extending down into the column of amatol. This type can only be used at the top of a charge in a well drill hole or in tunnel blasts.

Another, and the most popular type for well drill holes, has the amatol column in the middle of the primer can, that is, from the top down this has 9 inches of "Nitramon," then 6 inches of amatol, and finally 9 inches of "Nitramon" at the bottom. Along the outside of the can, parallel to the axis and adjacent to the amatol charge, there is a fluted metal tube or tunnel through which "Primacord" is run. These center-type primers can be located at the bottom, center, or top of the main "Nitramon" charge or in the deck loads. The amatol charge in these primers is, of course, detonated by commercial blasting caps or "Primacord," but it is insensitive to friction and will not detonate from the impact of .30 caliber ball ammunition.

Experience has shown that these special primers are more efficient for detonating "Nitramon" than 24-inch length columns of 60% dynamite or gelatin of the same diameter. When these primers are used with "Primacord" they represent the safest possible method of priming "Nitramon," and, hence, are strongly recommended. "Nitramon" can be detonated by high explosives (dynamite for dry work, and gelatin for wet work) but certain specified practices must be adhered to rigidly.

SMALL DIAMETER "NITRAMON"

"Nitramon" S. "Nitramon" is also supplied under the name of "Nitramon" S in cans 2 in. in diameter by approximately 6 in. long and weighing 1 lb net. The containers are carefully designed for ruggedness and resistance to water pressure. They are threaded male and female at opposite ends so that they can be joined securely with positive contact between cans. With this feature, charges can be conveniently assembled with as many units as desired to form a continuous column characterized by exceptional rigidity throughout its length. Consequently, "Nitramon" S can be loaded with ease under the most severe borehole conditions.

"Nitramon" S is sold in two style packages. The first has 50, 2-in. diameter by 1-lb cans per 50-lb box. The second has 11, 2-in. by 4-lb units (each being 4, 1-lb cans screwed together at the mill) and 6, 2 in. by 1-lb units per 50-lb box. The 4-lb units are for convenience in making up charges of 5 lb or more.

Fig. 11—Can of "Nitramon" S and primer for 'Nitramon" S

"Nitramon" S possesses strength and velocity comparable to that of the gelatin dynamites normally employed in seismic prospecting. Actual field tests have demonstrated that comparable seismograph records are obtained when a given weight of 60% gelatin is replaced by an equal weight of "Nitramon" S and primer.

Primers. A special primer of amatol, also packed in 2-in. diameter by 1-lb cans must be used with each charge to initiate the "Nitramon" S assembly. The cans are similar to the 2-in. diameter "Nitramon" cans with male and fe

male threads, the male end for attaching to a charge of "Nitramon" and the female end to receive a special shield for protecting the electric blasting cap which is inserted in the tube extending into the primer from the center of the female end. These primers are about 6 in. in length and are packed 50 primers to a 50-lb wooden case. The strength of the "Nitramon" S primer is equivalent to that of 1 lb of 60% gelatin dynamite, so that it is used alone where 1 lb of gelatin would normally be fired, and as 1 lb of explosive energy in "Nitramon" assemblies of 2 lb or more total charge.

The shields referred to as being used with "Nitramon" S primers not only afford protection to the electric blasting cap, but also act as an anchor for the cap leg wires and provide a strong, hard surface for loading poles when the latter are necessary in order to push charges down through obstructed boreholes.

CHAPTER IV

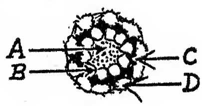
BLASTING SUPPLIES

For priming charges of explosives by approved methods, one or more of certain products or devices are employed and they are invariably consumed in the blast. These materials are grouped under the name of "blasting supplies." In this chapter they are discussed under three headings: igniters, detonators, and detonating fuse.

IGNITERS

Safety Fuse. Safety fuse is a medium through which flame is conveyed at a continuous and uniform rate for the direct firing of an explosive charge, as in the case of the ignition of black blasting or pellet powder, or for indirect firing, as in the case of the ignition of a blasting cap to detonate dynamite. Safety fuse consists of a train of black powder tightly wrapped and enclosed in various wrappings of textiles and waterproofing materials. The powder is the active element in fuse and is protected from abrasion and penetration of water by the coverings of tapes and yarns and coatings of waterproofing materials. Another function of the coverings is to prevent intercommunication of firing between adjacent lengths of fuse

Fig. 12—Cross section of safety fuse enlarged showing (a) the powder train, and (b), (c), and (d) the layers of protecting and waterproofing materials. The powder train burns while the protecting layers do not.



and to minimize the chance of setting fire to the charge of explosives by sparks coming through the side of the fuse before the fire has reached the end. Bearing in mind the purpose and relatively simple construction of fuse, it can readily be seen that any practice which may lead to rupturing or otherwise damaging the protective coatings, or to permitting water or other substances to reach the powder core will result in faulty performance.

There are two types of fuse, in one of which the powder train consists of a free powder core and the other a semi-solid

powder core. When free core fuse is in good condition, the powder grains appear clean and distinct. When cutting, and particularly when slitting this type of fuse, care must be taken not to allow the powder train to fall out. The powder train in semi-solid core fuse is a semi-solid mass, gray in color, which clings to the winding threads about the core and to the core threads themselves, consequently little powder falls out when the fuse is slit. It can be quickly and easily lighted. When free core fuse has become damp and dried out again it hardens into grayish lumps that cling to the wrapping threads and it is then difficult to distinguish this type of fuse from semi-solid core fuse. The surest way to distinguish between these types is to examine the powder core and determine the number of center threads; free core fuse has a single center thread, while semi-solid core fuse has two or more.

Safety fuse is also made in two distinct speed ranges, namely, approximately 120 seconds per yard and approximately 90 seconds per yard. The manufacturers state that they use every care and precaution in the manufacture of safety fuse and endeavor to bring their product, when burned in the open at sea level, to those standard burning speeds within an allowable variation of 10% either way from standard. The manufacturers make no warranty or representations, however, as to the burning speed of their product owing to the many circumstances and conditions to which fuse is subjected after leaving the factory, including differences in altitude, weather conditions, conditions of storage, character of tamping and mishandling, all of which affect the burning speed of fuse.

Because of the many kinds of stemming material and different degrees of tightness of tamping, there can be no absolute standard rate of burning speed in the confinement of the borehole. The greater the confinement, the faster fuse will burn, and the burning speed under these conditions may be appreciably faster than in the open. Some brands of semi-solid core fuse accelerate less than free core brands, which is one of the advantages of the former. A reduction of external pressure, on the other hand, slows down the burning speed of fuse, and elevation above sea level must therefore be taken into consideration.

There is a large number of brands of safety fuse sold and used in this country. These brands vary quite widely in their ability to withstand water, temperature changes, handling, and in other respects. Table VI shows the characteristics of the brands most highly recommended.

TABLE VI

Characteristics of Recommended Brands of Safety Fuse

See Notes	Brand	Color	Surface	Core	Speed—see note (d)	Water Resistance	Flexibility
(a)	Gray Charter Oak........	Gray	Corrugated	Free	120	Good	Good
(a)	Black Wax Charter Oak...	Black	Semi-smooth	Free	120	Good	Good
(a)	White Wax Clover........	White	Semi-smooth	Semi-solid	120	Excellent	Excellent
(a)	Orange Wax Clover.......	Orange	Semi-smooth	Semi-solid	120	Excellent	Excellent
(a)	Crescent................	White	Corrugated	Free	90	Good	Fair
(b)	Black Monarch..........	Black	Semi-smooth	Free	120	Good	Excellent
(b)	Black Aztec.............	Black	Semi-smooth	Semi-solid	120	Excellent	Excellent
(b) (c)	Bear....................	White	Corrugated	Free	120	Good	Fair
(c)	Dreadnaught............	Black	Semi-smooth	Free	120	Good	Excellent
(c)	Black Sequoia...........	Black	Semi-smooth	Semi-solid	120	Excellent	Excellent

(a) Sold in states east of Montana, Wyoming, Colorado, and New Mexico.
(b) Sold in the states of Montana, Wyoming, Colorado, Utah, and New Mexico.
(c) Sold in states west of Montana, Wyoming, Utah, and New Mexico.
(d) Speed in seconds per yard, burned at sea level and subject to an allowable variation of plus or minus 10%. Brands (b) sold in Montana, Wyoming, Colorado, Utah, and New Mexico, are manufactured in Denver at elevation of approximately 5,000 ft and their standard speed at the factory is approximately 126 seconds per yd.

Safety fuse is manufactured in 50-ft lengths which are coiled and wrapped in packages containing two such coils or 100 ft. These packages, in turn, are sold in cases containing

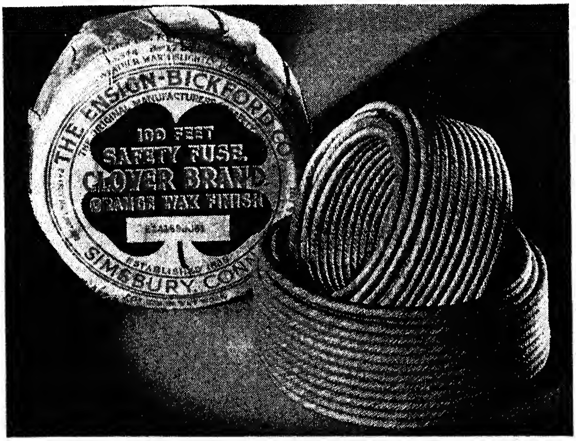


Fig. 13—Rolls of safety fuse

1,000, 3,000, or 6,000 ft respectively. For large consumers safety fuse is also available in single reels containing 3,000 ft.

Additional information on safety fuse can be obtained from publications issued by the manufacturers.

Miner's Squibs. A miner's squib is essentially a small, rocket-like device used for firing charges of black blasting or pellet powder. It consists of a thin paper tube of powder sealed at one end by a wax plug and ending at the other end in a tail which consists of twisted, impregnated paper acting as a wick or fuse. The wax plug is merely a seal for one end of the tube to protect the powder content from moisture and is pinched off at the time the squib is used. The squib is shot into the powder charge through a small channel left in the stemming material. At the time it is ignited it is placed in the channel at the mouth of the borehole. The tail is lighted by a match or an open light and the fuse burns slowly so as to give the blaster sufficient time to retire to a place of safety before the squib proper fires. When firing occurs, the rocket effect of the powder-filled tube forces the squib through the

channel provided and into the charge where the flame of the squib ignites the powder.

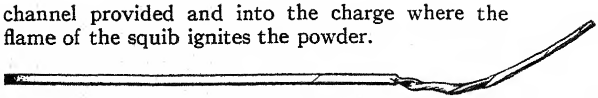


Fig. 14—A miner's squib

While the miner's squib is a very low cost means of firing black powder, there are numerous objections to it. A considerable amount of smoke is given off by the squib itself and the needle hole required to give it access to the powder charge sometimes reduces the effectiveness of the stemming material. Most important, however, is the fact that the squib may be stopped in the needle hole by slight obstructions and this is responsible for a large number of delayed blasts or misfires. One method of preventing this trouble is to use a piece of ¼ in. gas pipe, called a blasting barrel, instead of the miner's needle.

Electric Squibs. Du Pont Electric Squibs comprise an aluminum tube 1½ in. long with a charge of deflagrating mixture in the bottom closed end, and with an electrical firing element and attached leg wires sealed into the other end with waterproofing compound and sulfur. The electric squibs are thoroughly waterproof and will stand immersion in wet holes several hours—much longer than the black powder charge which they are intended to ignite. When current is applied to the leg wires, the firing element flashes, ruptures the shell, and ignites the deflagrating compound. Intense flame, sustained by the latter, issues from the ruptured shell into the charge of blasting powder or pellet powder.

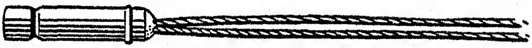


Fig. 15—A Du Pont Electric Squib

These electric squibs will ignite pellet powder which is too wet for firing with either miner's squibs or safety fuse. In addition, they permit tight tamping of the borehole, the ignition of the powder charge at any desired point, the firing of a number of shots at the same time, and definite control of the time of firing of the charge; and they eliminate smoke other than that produced by the black powder. Electric squibs are considered the safest and most effective means of firing

black blasting or pellet powder and their use, therefore, is strongly recommended.

Du Pont Electric Squibs are available with impregnated cotton-covered iron or copper leg wires in standard lengths of 4, 6, 8, 9, and 10 ft. They are packed 50 to the carton, and 10 cartons or 500 squibs to the case.

They are provided with metal foil shielded shunts and, where desired, in various types of special wire folds and packages, all of which are described in connection with electric blasting caps.

Delay Electric Squibs. Du Pont Delay Electric Squibs have copper shells coated with gray lacquer. They are similar to Du Pont Electric Squibs except that delay elements providing ten periods of delay of approximately 1 to 2 seconds each are inserted between the firing element and the deflagrating charge.

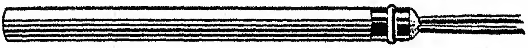


Fig. 16—A Du Pont Delay Electric Squib

The shells vary in length from 3⅛ in. for the first delay to 5⅞ in. for the tenth delay period. Their water resistance and igniting characteristics are the same as regular electric squibs. As indicated by their name, however, they also permit shooting of charges in rotatio

Delay Electric Igniters. These are made up of a copper tube with an electrical firing element and leg wires sealed into one end, and a piece of fuse crimped into the other. The lengths of fuse vary from 3 in. upward, increasing by 2 in. increments, to provide first, second, third, and higher delay periods. The free end of the fuse is protected by a waterproofing dip; about

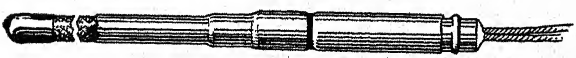


Fig. 17—A Du Pont Delay Electric Igniter

1 in. must be cut from the end of the fuse to remove this dip and properly expose the core of the fuse before use. They are sometimes used for rotation firing of charges of black powder but are much more commonly employed to ignite blasting caps for detonating charges of dynamite. They are rapidly being replaced in field use by delay electric squibs or delay electric blasting caps.

DETONATORS

Blasting Caps. Blasting caps are the detonators used for firing high explosives when electric blasting is not practiced. They must always be fired by fuse, and are in no way interchangeable with electric blasting caps. It is not possible to fire a number of blasts simultaneously with blasting caps and fuse but rotation shots are so fired by using fuse cut in different lengths to give the desired rotation.

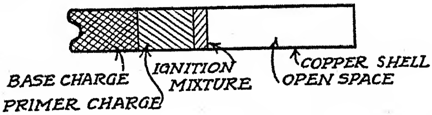


Fig. 18—Principal components of a Du Pont Blasting Cap

Blasting caps are small tubes, usually copper, closed at one end and loaded with a charge or charges of explosives, at least one of which is capable of detonating from the spit or sparks from safety fuse. Those of du Pont manufacture have a charge of a high velocity explosive, tetryl, in the base of the cap, with a primer charge and an ignition charge superimposed upon it. This combination has proved to be an extremely efficient and dependable detonator and hence one with maximum safety in use. Du Pont Standard (No. 6) Blasting Caps are 1½ in. long with approximately ¾ in. open space above the charges for insertion of fuse. A stronger (No. 8) cap is also manufactured but it is now used very infrequently and is not recommended because of its higher cost.

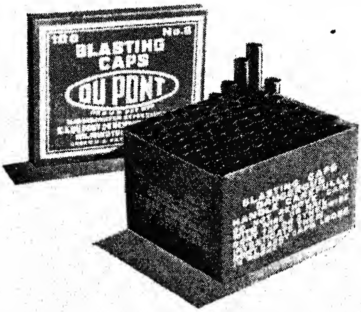


Fig. 19—An open box of 100 Du Pont Blasting Caps showing several caps partially removed

DuPont Blasting Caps are packed in metal boxes, 100 to the box, and these metal boxes in wooden cases containing from 500 to 5,000 caps.

Electric Blasting Caps. Electric blasting caps, as the name implies, are blasting caps provided with a means for firing by an electric current. With them it is possible to initiate one or a num-

ber of charges of high explosives instantaneously. The du Pont Company manufactures regular (No. 6 strength standard) electric blasting caps for general use and several modifications designed for specific purposes.

The standard Du Pont Electric Blasting Cap has a 1⅝ in. long copper shell. It has a base load of tetryl, a pressed primer load and a loose ignition charge. The electrical firing element consists of two leg wires, a sulfur composition bridge plug which holds the two leg wires in place, and a small diameter corrosion-resistant bridge wire attached across the terminals

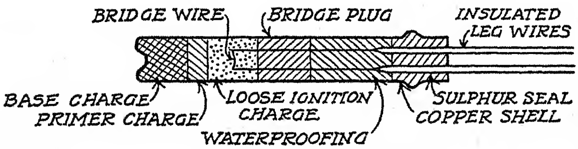


Fig. 20—Principal components of a Du Pont Electric Blasting Cap

of the leg wires about 3/16 in. below the plug. This firing element is placed in the cap so that the bridge wire is embedded in the loose ignition charge and then sealed in place by a pour of waterproofing material, and finally a pour of sulfur. Upon application of the electric current, the bridge wire heats up to incandescence and fires the cap.

The leg wires on these electric blasting caps are plain copper in lengths under 12 ft and enameled copper in lengths of 12 ft and over. They are insulated with asphalt impregnated windings of cotton yarn. The standard wire lengths are 4, 6, 8, 10, 12, 16, 20, 24, 30, 40, 50, 60, 80, and 100 ft.

The standard electric blasting caps described have remarkably good water-resisting ability and are regularly used under water where conditions are not too severe. They are not intended, however, for submarine blasting or other work where they would be under high water pressure. For such work the first of the modified caps mentioned above, Du Pont Waterproof Electric Blasting Cap, is recommended. The latter caps are the same as the standards except that they have longer shells so that more waterproofing compound can be provided above the bridge plug, and they have enameled copper wires in all lengths. They are also supplied with duplex enameled copper wires in standard lengths of 20 ft and over.

For coal mines Du Pont Electric Blasting Caps are provided with white, wax-impregnated, cotton-covered iron leg wires.

The white wires can be seen better than black wires in coal. The iron wires can be removed from the broken coal by magnetic separators installed at many mines and they are cheaper than copper wires. Iron wire caps are not satisfactory for general use because the electrical resistance of iron is about six times that of copper and a given blasting machine cannot fire nearly as many electric detonators with iron wires as when copper wires are used. The iron wire caps are satisfactory in coal mines, however, because generally only one shot and invariably only a few shots are fired at one time. Furthermore, short length wires only are supplied with these caps, the standard lengths being 4, 6, 7, 8, 9, 10, and 12 ft. Du Pont Electric Blasting Caps for coal mines have another, and particularly important, feature: the ignition mixture in these caps burns at a sufficiently slow rate so that the caps do not detonate until after the current flowing from a blasting machine has been reduced to a point that it cannot arc across the leg wire terminals. This feature eliminates one hazard that otherwise attends blasting in gassy and dusty mines.

Experience has shown that when copper-shell, copper leg wire electric blasting caps are used in blasting salt, small particles of copper remain in the product. When such salt is used in the tanning of hides, the latter become stained. Du Pont Electric Blasting Caps for salt mines have aluminum shells and iron wires with black cotton insulation. These iron wires cause an undesirable stain in salt used for certain purposes but they can be removed by magnetic separators. The black insulation is provided, of course, so that the wires can be more easily seen when connecting up blasts.

In seismograph work essentially all crews now operating in this country connect the electric blasting caps used to fire the charges of explosives into the timing circuits of their recording instruments in order to secure a zero time reading. Some circuits are arranged so that the time of application of current to the firing line becomes the zero point. In the large majority of circuits, however, the time of breakage of the bridge wire in the electric blasting cap is the zero point. In either case it is necessary to know the time lag between the zero point and the detonation of the charge. Du Pont "SSS" Seismograph Electric Blasting Caps have a minimum of time lag between the application of the current and the breakage of the bridge wire and no time lag between the latter and the detonation of the cap. As a consequence, they are exceptionally well suited for use in seismic prospecting. These timing

characteristics are obtained by changes in the ignition compounds and charges employed. The "SSS" Electric Blasting Caps are provided with enameled copper wires in all lengths and are supplied in the same standard lengths as regular electric blasting caps, but they have yellow instead of black insulation. Du Pont "SSS" Seismograph Electric Blasting Caps should not be used for multiple firing.

Du Pont Regular Electric Blasting Caps, Waterproof Electric Blasting Caps, and "SSS" Seismograph Electric Blasting Caps are also manufactured in No. 8 strength. These stronger caps, however, are seldom, if ever, necessary in blasting.

It has been previously mentioned that these three latter types of Du Pont Electric Blasting Caps are supplied with enameled copper wires in certain lengths. The enamel coating prevents water which has penetrated the cotton insulation from reaching the copper. If water does reach the copper it may form a short circuit through which the electric current may pass instead of going through the bridge wire. This is particularly likely to happen if the water contains mineral salts leached from the ground. If short-circuiting occurs, misfires result. Misfires in what would ordinarily be considered relatively dry work, especially of some of the center holes in a long series shot, have been traced to this cause. Enameled wires are, therefore, recommended for blasting when water is present and particularly if multiple firing is employed. A warning should be issued, however, that when the wires of enameled wire electric blasting caps are cut, care must be taken to scrape off the enamel as well as the insulation, in order to insure a good electrical contact. The safest practice is never to cut the wires of enameled wire caps but always to make connections on the tinned ends.

Short-circuiting the wires of electric blasting caps and other electrical firing devices guards against premature firing through accidental contact between the wires and an electric current. The use of short-circuited devices is an extremely important safety measure in any operation where stray currents may exist, or where there is a possibility of contact between the ends of the wires and electrically charged rails, pipes, or machinery. The du Pont Company supplies and strongly recommends its metal foil shielded shunt. This consists of a metal foil with a coating of insulating material on one side, secured on the bare leg wires with the insulating coat next to the wires. It extends from a position well up on the insulation on the leg wires to at least ⅛ in. beyond their ends. This shielded shunt forms

TABLE VII

Identification of Du Pont Electric Blasting Caps

TYPE	STRENGTH	SHELLS				WIRES	
		Material	Diameter	Length	Coloring	Material	Color
Regular E. B. Caps	Standard	Copper	0.273″	1 5/8″	Red	Copper	Black
Regular E. B. Caps	No. 8	Copper	0.273″	1 7/8″	Red	Copper	Black
Waterproof E. B. Caps	Standard	Copper	0.273″	2 3/4″	Red	Copper	Black
Waterproof E. B. Caps	No. 8	Copper	0.273″	3″	Red	Copper	Black
Coal Mine E. B. Caps	Standard	Copper	0.273″	1 5/8″	Red	Iron	White
Salt Mine E. B. Caps	Standard	Aluminum	0.288″	1 3/8″	Red	Iron	Black
"SSS" Seismograph E. B. Caps	Standard	Copper	0.273″	1 3/4″	Blue	Copper	Yellow
"SSS" Seismograph E. B. Caps (Waterproof)	No. 8	Copper	0.273″	3″	Blue	Copper	Yellow

NOTE: Du Pont Electric Blasting Caps should not be fired in the same series with the products of other manufacturers.

a short circuit of the leg wires throughout the entire length of their bared ends and in addition shields the wires from contact with electric currents. A shunt should never be removed from an electric firing device until the moment of connecting the wires into a blasting circuit. The du Pont shielded shunt is more easily removed than other types of shunts—by simply pulling the wires apart—and no time is wasted at the scene of the blast through its use. There is, therefore, a far greater tendency on the part of miners to keep the shielded shunt in place, as directed, right up to the time of hooking up the shot. The du Pont shielded shunt is standard on all electric blasting caps with wires 12 ft long or less and may be obtained without extra cost on longer length electric blasting caps and all other firing devices (squibs, delay electric squibs, delay electric igniters, and delay electric blasting caps) by so specifying.

When the wires of electric blasting caps or other electric firing devices are unfolded, particularly if this is done carelessly, the wires sometimes tangle and kink. In tamping boreholes containing kinked wires, the insulation is frequently rubbed or scraped off. Short-circuiting of the wires and misfires result. To minimize kinking of wires, the du Pont Company furnishes a figure-8 fold with the wires held in position by a

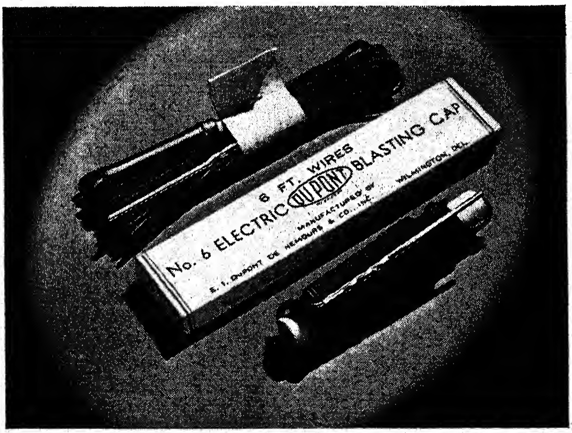


Fig. 21—(LEFT) Figure-8 fold, banded Du Pont Electric Blasting Cap (MIDDLE) Individual flat package for same; (RIGHT) Spiral wound Du Pont Electric Blasting Cap

paper band. When one is ready to prime with the firing device, the band is simply torn off and the wires unfold without tangling or kinking. Figure-8 fold, banded firing devices with wires 12 ft long or less can also be obtained packed in a handy individual flat carton. As an alternative, electric blasting caps with wires 16 ft long or less may be obtained with the caps inserted in and the wires coiled around a cardboard tube, this packing being termed "spiral wound."

Electric blasting caps with wires 16 ft long or less are packed 50 to the pasteboard carton, and 10 cartons or 500 caps to the wooden case. Those with longer wires are packed with fewer than 50 to the carton, the number depending on the wire lengths.

Delay Electric Blasting Caps. Delay electric blasting caps are similar to electric blasting caps except that a delay element is inserted between the electrical firing element and the detonating charges. They are used to detonate charges of dynamite in rotation and their advantage over the use of caps and fuse for this purpose lies in the fact that the timing of the several delayed shots is more accurate. Rotation firing has the general advantage, of course, that complete rounds can be fired without returning to the face between blasts.

Du Pont Delay Electric Blasting Caps are manufactured in ten standard periods of delay, the length of the cap shells

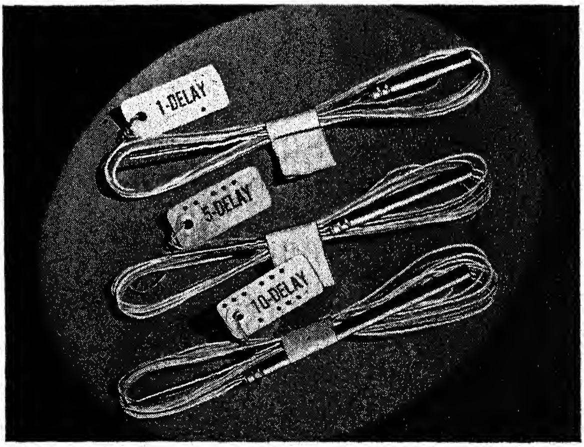


Fig. 22—1st, 5th, and 10th Du Pont Delay Electric Blasting Caps

varying from 2 in. for the first delay to 4¾ in. for the tenth delay. The delay elements are metal carriers containing a mixture which produces no gas on burning. The time interval of delay for the first period is approximately one second, and the time intervals increase gradually up to approximately two and one-half seconds between the ninth and tenth periods. The delay electric blasting caps of any given period do not all detonate at precisely the same time, which fact is of advantage in many operations since it reduces the violence of the blast for any given period of delay. The caps of any delay period do fire sufficiently near the same time, however, so that they invariably detonate before any caps of the next delay period; in other words, there is no overlapping of delay periods. Du Pont Delay Electric Blasting Caps differ from those of many manufacturers in that they are contained in shells of the same diameter as electric blasting caps and these shells have no perforations for venting the gases formed on combustion of the powder in the delay element. The small uniform diameter shell makes for easier priming of dynamite cartridges. The ventless feature insures a more uniform rate of burning of the delay element, eliminates the possibility of igniting the dynamite charge, and eliminates damping out of the flame in the delay carrier when the caps are fired under water. The electrical firing element for these delays consists of a rubber bridge plug which is crimped into the shells with a double crimp, thus making these caps far more waterproof than electric blasting caps.

Du Pont Delay Electric Blasting Caps are provided with copper wires insulated by a plastic material. This material has dielectric qualities equal to enamel, and abrasion resistance superior to cotton-covered enameled wire. It has the distinct advantage that when the wires are scraped, the material is removed easily and completely, and hence it is easier to make proper connections. The wires for these delays are furnished in the same standard lengths as for regular electric blasting caps. One wire is colored yellow and the other red in order to facilitate connecting up in parallel.

These delay electric blasting caps can be fired in the same series with regular electric blasting caps, thus giving a total of eleven periods when necessary, but it is preferable to put the regular electric blasting caps in one series, the first delays in another series, the second delays in a third series, and so on and then to connect all the series in parallel.

DETONATING FUSE

"Primacord." "Primacord" is a detonating fuse comprising a high explosive core of pentaerythritetetranitrate (PETN) contained within a waterproof sheath overlaid by reinforcing coverings. It has a very high velocity, detonating at about 20,300 ft per second (nearly four miles per second). "Primacord" is light in weight and very flexible, making it easy to handle and connect. It has good tensile strength and is quite water resistant. "Primacord" is used principally in multiple shooting in deep well drill holes and in similar large blasts. The violence with which it explodes is sufficient to detonate high explosives lined alongside it in a borehole and a column of dynamite loaded alongside "Primacord" in a deep hole detonates practically instantaneously throughout its entire length.

In spite of its high velocity and violence of detonation, "Primacord" is very insensitive, and experience has indicated that it cannot be exploded by fire, friction, or ordinary shock, nor by firing a 30-caliber Springfield steel-jacketed bullet through a spool of it. However, since this material contains a high explosive, it is recommended that it be handled and stored as an explosive. The proper method of initiating "Primacord" is to detonate it with a blasting cap or an electric blasting cap butted against its end.

"Primacord" can be stored for extended periods even in the hottest climates without suffering deterioration. The melting point of the PETN core is 284° F., which affords a wide margin of storage safety. Under abnormal circumstances, there might be a noticeable softening of the protective asphaltum compound, evidenced by the presence of little beads of asphalt. This will not affect the water-resisting quality nor will it affect the PETN core or interfere with "Primacord" efficiency.

TABLE VIII
Standard Properties of "Primacord"

Type	Average Velocity Feet per Second	Diameter Inches	Tensile Strength Pounds	Shipping Weight	
				500 Feet	1,000 Feet
Plain	20,300	0.210	110–115	11 lb	19 lb
Reinforced	20,300	0.210	155–160	12 lb	20 lb
Wire Bound	20,300	0.224	200+	19 lb	35 lb

"Primacord" is furnished in three types: (1) Plain, which is provided only with a cotton covering; (2) Reinforced, which is the same as plain except for additional cotton covering; and (3) Wire Bound, which has both wire and cotton coverings and which is designed to have additional tensile strength and resistance to abrasion and shearing. The properties of the three types of "Primacord" appear in Table VIII.

Wire Bound "Primacord" is recommended for branch lines in all holes to be loaded with "Nitramon" and in deep, ragged holes to be loaded with explosives. Reinforced "Primacord"

Fig. 23—"Primacord" detonating fuse packed on wooden spools containing 500 and 1,000 ft

should be used for all other holes loaded with explosives. Either plain or reinforced "Primacord" may be used for the trunk line.

"Primacord" is packed on wooden spools containing 500 ft or 1,000 ft each. Each spool has a hole in the center through which a rod may be run to facilitate unwinding.

"Cordeau." "Cordeau" was the original detonating fuse consisting of a core of trinitrotoluene (TNT) enclosed in a lead covering. Its manufacture has been discontinued in favor of "Primacord" which covers the same range of application and has many advantages. "Primacord" is more flexible and easier to handle, more positive in action, and more water resistant. "Primacord" will also withstand rougher usage without mechanical damage and retains its efficiency over longer periods of storage, particularly in hot climates.

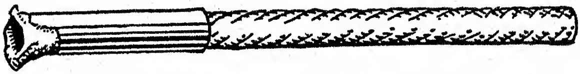
CHAPTER V

BLASTING ACCESSORIES

Various devices and materials are used in connection with blasting in addition to the blasting supplies employed in making up primers. These are termed "blasting accessories." While some of these accessories are consumed in the blast, many of them are designed to serve the blasting operations repeatedly. Blasting accessories are here described under the captions: fuse lighters, cap crimpers, blasting machines, testing instruments, and miscellaneous accessories.

FUSE LIGHTERS

Ordinary matches are most frequently used to light a single fuse but these are not satisfactory for lighting a number of fuses because this usually must be done in a very short time. Primers made up with fuse and caps and trimmed to fire in rotation must be lighted quickly, surely, and in a certain order. This is best done with a lighter designed for the purpose.



Safety Fuse Match Lighter. This consists of a short paper tube which can be slipped over the freshly cut end of safety fuse. One end of the tube is coated with the same composition as that used on safety matches. This matchhead composition is lighted by striking it on the edge of a safety match box or by applying a flame to

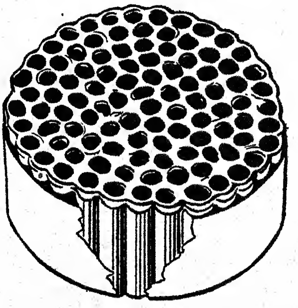


Fig. 24—Safety Fuse Match Lighters showing one detached and placed on end of fuse

it. The burning matchhead then produces enough flame to ignite the exposed end of the fuse.

Lead Spitter Fuse Lighter. This is a coil of thin lead tubing filled with black powder and wound on a reel. The powder is easily ignited and burns at a speed of about 36 sec per ft, giving a continuous spit of flame like that of a burning fuse. The intense heat of the flame will ignite the end of safety fuse so that it is unnecessary to slit the fuse before lighting. A knife is attached to the holder to cut off the lead tubing. To avoid the possibility of fire getting into the spool, it is preferable to cut off the length of lead tube required before lighting it.

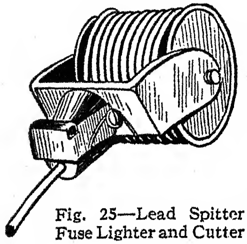


Fig. 25—Lead Spitter Fuse Lighter and Cutter

Pull Wire Fuse Lighter. This is a hollow paper tube containing an ignition compound and made to fit over the end of safety fuse. In use, the fuse is inserted into the open end of the lighter where it is held securely by an arrangement of teeth which grip the fuse if an attempt is made to pull it out. The fuse is lighted merely by pulling on the wire. The Pull Wire Fuse Lighter is very convenient when it is necessary to light fuse in the wind or rain. This is true also when it is desirable to light fuse from a distance, as for example, when a charge is loaded in or near the roof in high places, in which case a string is tied to the protruding wire.

Fig. 26—A Pull Wire Fuse Lighter on end of fuse

Hot Wire Fuse Lighter. This device is similar to a fireworks sparkler. It consists of a wire covered with a moisture-proofed composition which burns slowly and at a fairly steady rate with an intensely hot ring of fire. The Hot Wire Fuse Lighter is lighted by a match and then can be used to ignite fuse merely by holding the burning portion of the lighter against the freshly cut end of fuse.

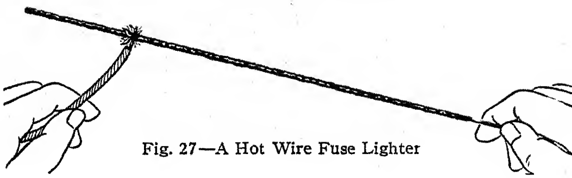


Fig. 27—A Hot Wire Fuse Lighter

These lighters are supplied in two lengths—7 in. and 12 in. In the condition they leave the factory they burn in approximately 60 sec and 135 sec respectively. However, they take up moisture from humid atmospheres and their burning speed is thus retarded. Under no circumstances should they be considered a timing device. If cognizance is taken of this latter fact, these Hot Wire Lighters can be recommended as the most satisfactory means of lighting safety fuse.

Master Fuse Lighter. This lighter consists of a strong, waterproofed fiber shell, topped with a flexible rubber cover, and containing in the base a charge of ignition compound. It is intended for lighting two to six fuses simultaneously. To do so, each fuse leading to a borehole, trimmed for proper rotation firing, is pushed through the rubber cover until its end is in contact with the ignition compound in the base of the shell. A pilot fuse, also properly trimmed and of sufficient length to permit the blaster to retire to a place of safety, is inserted through the rubber cover and seated on the ignition compound. The rubber cover holds all fuses in position. Only the pilot fuse is lighted. This burns to the ignition compound in the shell which, in turn, ignites and lights the fuses leading to the boreholes.

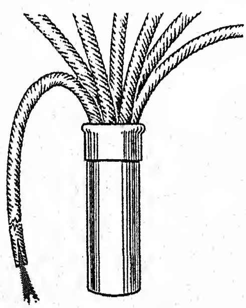


Fig. 28—A Master Fuse Lighter showing fuses inserted—six borehole fuses and single pilot fuse

The use of Master Fuse Lighters will insure better results in rotation firing and allow more time for the blaster to retire before detonation of the first blasts since he has only the pilot fuses to light. Their use has the disadvantage that generally more fuse is required, and hence the cost of blasting a round is higher.

CAP CRIMPERS

Blasting caps must be securely fastened to the safety fuse, both to prevent the fuse from being pulled out of them when the primer cartridges are loaded and the boreholes tamped, and also to facilitate the waterproofing of blasting caps and primers. Experience and careful tests have shown conclusively that blasting caps crimped tightly on the fuse are much more effective than those fastened loosely or not crimped at all. Crimping can be accomplished successfully only by the use of an instrument made especially for the purpose. Cap crimpers are essential for safety and for efficiency.

Hand Type. The Du Pont No. 2 Cap Crimper makes a flat sleeve crimp, leaving a small air vent so that for use in wet work the cap and fuse must be dipped in some waterproofing substance to protect the cap charge from water. It also has a fuse-cutting device which cuts the fuse square across.

The Du Pont No. 3 Cap Crimper makes a water-tight crimp (cut throat) on a smooth-covered fuse, so that no waterproofing is necessary. The crimp can be further improved by a second application of the tool, rotating the cap for the second bite about a quarter turn.

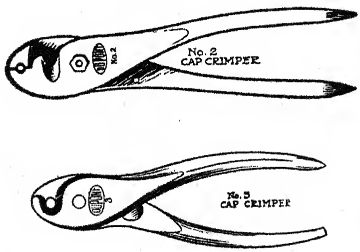


Fig. 29—Du Pont No. 2 and No. 3 Hand Cap Crimpers

Bench Type. The Du Pont Superior Crimper is a new bench-type cap crimper recently developed by du Pont engineers. The crimp made by this machine is not like the ordinary sleeve or segment type. It consists of two smooth continuous internal beads on the throat of the cap. These beads grasp the covering of the fuse so closely that a waterproof seal is made without the use of a waterproofing compound. Exhaustive tests have demonstrated that the Du Pont Superior Crimper makes a joint more waterproof than the fuse itself.

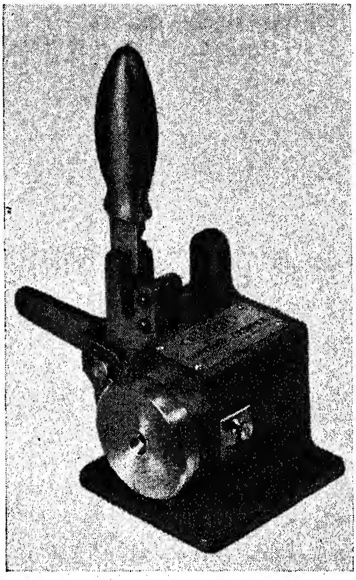


Fig. 30—Du Pont Superior Crimper

In operation the Du Pont Superior Crimper is mounted on a bench and the freshly cut end of the fuse is inserted into the cap as far as possible. Then the assembly is pushed into the throat of the crimper until it stops. Operating the handle once makes two crimps as shown in the illustration. The Du Pont Superior Crimper can be adjusted to crimp any commercial blasting cap now on the market. This is accomplished by inserting the stop plate in the proper manner in the horizontal slot in the front of the machine and by fastening it in place with a knurled nut.

This crimper is equipped with a fuse cutter and a guide which holds the fuse in line with the blade and insures a straight, square cut. Three fuses may be cut at one time. The cutter consists of a blade similar to a safety-

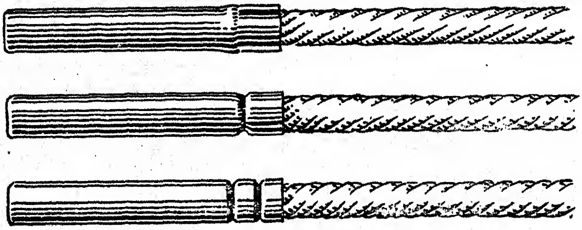


Fig. 31—Caps crimped on fuse showing (top) flat sleeve crimp made by No. 2 Hand Crimper, (middle) air-tight crimp made by No. 3 Hand Crimper, and (bottom) waterproof crimp made by Du Pont Superior Crimper

razor blade fastened to the handle by two screws. During cutting, it operates in a slot and when not in use it is protected by the body of the machine. The blade can easily be removed for cleaning or replacement and five spare blades are included with each crimper.

The Du Pont Superior Crimper may be operated by foot as well as by hand. For foot operation, however, a foot treadle and steel connecting rod must be provided by the user. The foot treadle is attached through the connecting rod to the arm which is part of every crimper. A counter weight attached to the connecting rod will facilitate opening of the jaws of the crimper and return of the foot pedal to the up-position.

BLASTING MACHINES

Blasting machines are used to generate current for firing blasts by electricity. They are operated in one or the other of two ways, either by a quick twist of the handle in the twist type, or by a downward thrust of the rack bar in the rack bar type. In either case, muscular energy is converted into electrical energy. Some blasting machines are magnetos but the large majority are modified generators. They are rated according to the number of 30-ft copper-wire electric blasting caps that they can be depended upon to fire in straight series. All du Pont blasting machines are ruggedly built and, given reasonable care, will withstand hard service for a long time.

Magneto Type. Du Pont Pocket Permissible No. 1 is a magneto which delivers alternating current. It is designed for firing one shot at a time but when strongly operated will shoot three or four caps. It has been declared permissible for use in gassy and dusty mines because its discharge does not have sufficient energy to cause a gas explosion.

Generator Type. Du Pont No. 10 Twist and Du Pont No. 10, No. 20, No. 30, No. 50, and No. 100 blasting machines are all generators which deliver a pulsating direct current. Their number indicates the rated capacity of each. Actually these ratings are conservative. The No. 30 and No. 50 machines are especially powerful and tests have shown that under favorable conditions they will fire three to four times as many caps as their rating would indicate provided the caps are connected in parallel-series with a maximum of 30 to 40 caps in a series.

These machines are so designed that no current flows from them until the twist or rack bar reaches the end of the stroke, then the current is released to the firing line at its peak amperage and voltage. This feature distinguishes them from a regular generator or dynamo built for delivering continuous current for power or lighting purposes.

Fig. 32—Du Pont twist-type blasting machines

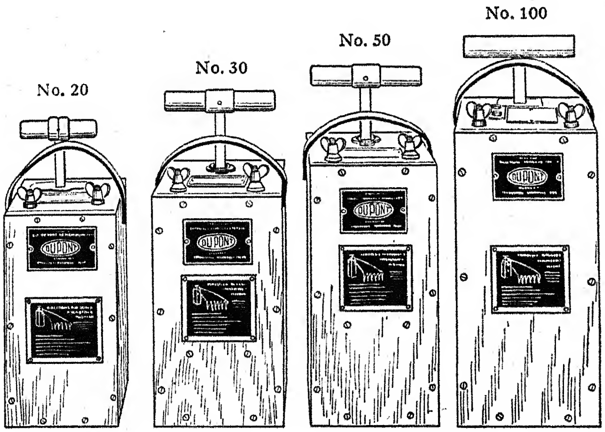


Fig. 33—Du Pont push-down type blasting machines of various capacities

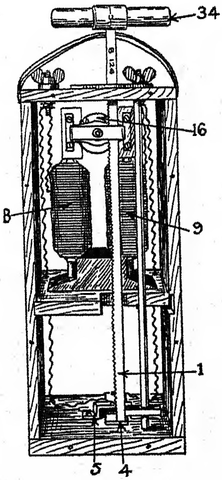


Fig. 34—Working parts of a push-down blasting machine. 1, rack bar, showing teeth which engage the pinion; 4, the contact spring, which, when struck by the bottom of the descending rack bar, breaks the contact between two small platinum contacts, one on the upper face of the contact spring 4, and the other on the underside of the bridge 5, and in this way throws the entire current through the outside circuit, that is, leading wire, electric blasting caps, and connecting wire; 8, 9, field magnets; 16, revolving armature; 34, rack-bar handle.

TABLE IX

Capacities of Blasting Machines

Name of Blasting Machine	Maximum Capacity using 30-ft copper-wire electric blasting caps in series	Shipping Weight Pounds		
		Gross	Net	Tare
Du Pont Pocket Permissible No. 1	1	5½	4½	1
Du Pont Pocket No. 10 Twist	10	5¼	5	¼
Du Pont No. 10	10	22	16½	5½
Du Pont No. 20	20	27	21	6
Du Pont No. 30	30	25	20	5
Du Pont No. 50	50	27	21	6
Du Pont No. 100	100	48	40½	7½

TESTING INSTRUMENTS

Du Pont Rheostat. This is an instrument used for testing the efficiency of a blasting machine in an economical and positive manner. It has a series of coils of varying resistances, each coil being equivalent in resistance to the designated number of electric blasting caps. One method of determining the capacity of a blasting machine would be to hook up a series of electric blasting caps and fire them, increasing the number of caps in a series until the capacity of the blasting machine was exceeded, as indicated by its failure to shoot the series with the largest number of caps. It is obvious, however, that this would be a costly process, especially in the case of high capacity machines, since several hundred caps might be destroyed before a conclusive test was completed. The purpose of the rheostat is to displace all but a few caps of a series by a resistance equal to that of the caps displaced. The method recommended for testing a blasting machine with the aid of a rheostat is described in Chapter X.

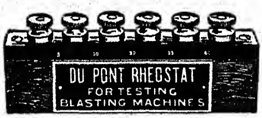


Fig. 35—Du Pont Rheostat

Du Pont Circuit Tester. This is an instrument used by blasters to test individual electric blasting caps or electric squibs; to determine whether or not a blasting circuit is closed and in the proper condition for the blast, or whether it is open, because of faulty connections or broken wires; or to indicate the existence of leaks or short circuits and the approximate resistance of a circuit.

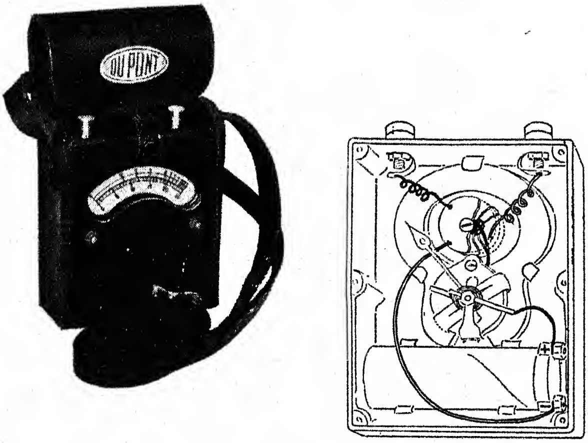


Fig. 36—Du Pont Circuit Tester with carrying case and strap, and interior of circuit tester showing wiring circuits

It is a magnetic device in which an electric current from a small silver chloride dry cell moves a pointer across a scale. The cell and needle are contained in a case made of phenolic composition and provided with two contact posts for connections. The instrument is in turn contained in a leather case cut out to show the scale and furnished with a carrying strap. Case and all, the circuit tester is small and flat, and is of a convenient size to carry in the pocket. The battery cell is one selected after a long series of experiments. While of long life and of great constancy, it is very weak. The current which is sent through an electric detonator, when making a test with the assembled instrument, is less than one-tenth of the strength required to explode it.

The operation of the circuit tester is quite simple. When a passageway (circuit) is offered so that the electric current can pass from one binding post to the other, the current from the battery cell flows through the circuit, traversing the circuit tester coil on the way, causing the pointer to be deflected.

In the sketch of Fig. 36 the solid black line ——— shows the path of the current from the positive pole of the silver chloride dry cell, through the coil which actuates the needle, through the winding of the spool within the electromagnet, and through a coil to one post of the circuit tester. The double line ═══ shows the path of the current from the other post of the circuit tester, through a coil leading to the spool, through another circuit on the spool, and thence into the negative pole of the dry cell

The fact that both the positive and the negative wires pass through resistances on the spool assures the safety of the circuit tester, for even if the current from one of these should be short-circuited there would still be sufficient resistance in the other path, in proportion to the weak current generated by the particular type of cell used, to safeguard against premature explosion of a blasting circuit in the process of testing with the circuit tester.

In use, the circuit tester in its leather case is carried at the blaster's side, slung from the strap which passes over his shoulder. To make a test it is necessary only to touch the ends of the two wires to the two contact posts. The instrument will work in any position. If there is a circuit, the indicator will immediately move over the scale. Breaks in the circuit are quickly located by following the simple instructions given in Chapter X. The circuit tester and the methods of using it are such as apply to the requirements of the practical blaster, as distinguished from the trained electrician, whose finer instruments and methods would be at a disadvantage under the conditions prevailing on the ordinary electric blasting job. Such extremely accurate electrical tests are seldom needed in blasting work.

This instrument is recommended because it is a convenience and a time-saver, and also because the more exact methods which it makes possible not only enable the blaster to secure better execution from explosives, but, most important of all, minimize danger and lessen the risk of blast failures and accidents.

MISCELLANEOUS ACCESSORIES

Du Pont Cap Sealing Compound. This is a material for making a water-tight seal between fuse and the shell of a blasting cap crimped to it. It is always necessary in wet work if a cap crimper similar to the Du Pont No. 2 Hand Crimper is employed. It is unnecessary, however, when using a Du Pont No. 3 Crimper with smooth finished fuse or a Du Pont Superior Crimper with any type of fuse. Du Pont Cap Sealing Compound is supplied in half-pint, pint, quart, and gallon cans.

Connecting Wire. This is No. 20, No. 21, or No. 22 copper wire insulated with two paraffin impregnated layers of cotton covering, counter-wrapped, and furnished on spools having one or two pounds of wire. It is used for splicing electric blasting cap wires where they are too short to reach between holes. The No. 20 runs about 210 ft, No. 21 about 260 ft, and No. 22 about 300 ft per lb.

Leading Wire. Leading wire is used to carry the current from a blasting machine or power circuit to electric blasting cap wires in the boreholes and return. It is supplied in coils of 100 ft, 250 ft, and 500 ft in length. Leading wire is made either single or duplex. Duplex leading wire is not recommended except for single shots. Stranded leading wire is not recommended for any type of blasting since breaks or partial breaks of the wire inside the insulation are difficult to detect.

Cotton-covered leading wire is suitable only for dry work. This is furnished in No. 14 and No. 16 gauge single, and No. 14 gauge duplex wire. Hazard Leading Wire, which has rubber and composition covering, is recommended for wet work. This is supplied in both No. 14 and No. 16 gauge single and duplex wire. For use in coal mines, where normally but one shot is fired at a time, rubber-insulated duplex wire of No. 18 gauge may be obtained.

Tamping Bags. Tamping bags made of heavy paper are used as containers for sand, clay, or other material for stemming. They save time and trouble when loading boreholes, particularly those pointing upward.

These tamping bags are made in eight different sizes as shown in the accompanying table. Actually, as delivered, the diameter is slightly larger than the specified diameter and the length is 2 in. longer than that specified. The latter provides for folding or lapping at the open end after the bags are filled. They are packed in bundles of 500 each, 10 bundles to the bale.

TABLE X

Tamping Bags

Designation	Size in Inches diameter length	Shipping Weight per bale
A	1 x 8	18 lb
B	1⅛ x 8	19 lb
C	1¼ x 8	20 lb
D	1¼ x 10	24 lb
E	1½ x 10	29 lb
F	1¼ x 12	28 lb
G	1½ x 12	33 lb
H	2 x 18	62 lb

Safety Blasting Cap Container. This is a small cylinder made of hard rubber composition with a rotating top closure. It holds 10 caps, well-protected and enclosed so that the caps will not fall out while being carried. By rotating the top, one cap can be removed at a time.

Powder Bags. The du Pont Company makes powder bags of varying capacities for carrying part cases of cartridges of dynamite and pellet powder. These are made of a material which is waterproof, acid resistant and a non-conductor of electricity. These can best be described by calling attention to the following table.

TABLE XI

Characteristics of Du Pont Powder Bags

Description	Customarily Used for	Type of Material	Size in Inches Width, Length, Depth	Approx. Capacity 1¼" x 8" Ctgs.
No. 1........	Dynamite	Ventube Cloth	6 x10 x12	50
No. 2........	Dynamite	Ventube Cloth	4½x12 x20	100
No. 3........	Dynamite	Ventube Cloth	6 x12 x20	125
No. 4........	Pellet Powder	Jute Fabric	3½x8½x9½	25
No. 5........	Pellet Powder	Jute Fabric	3½x8½x9½	15

Blasting Mats. Blasting mats are heavy mats woven of hemp rope, or of steel wire rope, or chains which are placed over the loaded holes just before firing to catch or hold material flying from the blast. The rope mats are made of 1 in., 1¼ in., or 1½ in. rope, according to the demands of the customer. They are not carried in stock, but are woven on order and are made in any size required. If the blasting mats are to cover light charges of explosives they may be spread directly over the boreholes; if heavier charges are used, railroad ties or logs should be put down first and the mats on top of them. Sometimes the hemp mats are propped on lightly supported apparatus several feet above the blast so that when the blast is fired the debris is caught on the underside of the mat. The woven steel mats are very effective for holding down the stone from a blast, but they are so heavy that they are practical only where there is a crane on the work to handle them. If steel mats are used, care should be taken to keep them from touching bare connections in the electric blasting circuit, as such contact would be likely to cause a short circuit and misfire.

Use is also made of fiber board, heavy planks, timbers, crossties, logs, and brush. These are placed over the blasts to form a blanket for holding down the broken fragments that might fly from the blast. As practically all blasting conditions vary, little exact advice can be given, so the blaster must depend largely on his own judgment in placing mats.

These arrangements are very effective in preventing the rock from being thrown into the air, and should always be adopted when blasting is done near thoroughfares or buildings.

CHAPTER VI

HANDLING AND STORAGE OF EXPLOSIVES AND BLASTING SUPPLIES

From the time explosives and blasting supplies leave the manufacturer's hands until they are consumed in blasting, they go through many handlings: transportation by common carriers and trucks, transfer to the consumer's storage magazine, then possibly to a distributing magazine, and finally to the scene of their use. In addition to being moved about and handled, they are also subject at intermediate stages of their existence to various periods of storage. The handling and storage of explosives and blasting supplies, from beginning to end, require proper procedures and methods entailing compliance with the law, regard for the protection and preservation of these somewhat perishable materials, and consideration of the hazardous nature of such products.

TRANSPORTATION

The transportation of explosives by common carriers on land or water is thoroughly regulated by the Interstate Commerce Commission and all persons having occasion to make shipments by common carriers are required to comply with these regulations.

Special attention is called to the Federal Act of March 9, 1921, which provides in Sections 232, 233, 234, 235, and 236 that it is a criminal act:

To carry or cause to be carried any explosives (other than exceptions named) in a train, boat, trolley, or other vehicle carrying passengers for hire; —or

To deliver or cause to be delivered to a common carrier for transportation any explosives under false or deceptive marking or description on the package, invoice, or shipping order; —or

To violate or cause to be violated any regulations of the Interstate Commerce Commission relating to the marking, shipping, or handling of explosives.

A violation of any of the provisions of this law is punishable by fine of not more than $2,000 or by imprisonment of not

more than eighteen (18) months, or both; or if injury or death results from such violation, by fine of not more than $10,000, or by imprisonment for not more than ten (10) years, or both.

Any person having occasion to transport, handle, store, or use explosives should familiarize himself with the federal, state, and local laws and regulations and comply with them.

Transfer of Explosives to Consumer's Magazine. So far as an operator is concerned, whether he be engaged in quarrying, mining, construction work, or agricultural blasting, responsibility for the safe handling of explosives begins with the transfer of explosives from the railroad car, the manufacturer's or dealer's magazine, or the manufacturer's or dealer's truck into his possession.

In the case of carload shipment, an inspection should be made on the arrival of the car at the railroad destination to ascertain whether its contents are in proper condition. Occasionally rough handling in transit may break open the cases or kegs in which dynamite and black powder are packed, so that there will be loose explosives between containers and on the floor. If inspection reveals such a condition, the workmen who are to unload the car should be warned to avoid every chance of friction, sparks, or fire that might cause an explosion of the loose and the whole material. As soon as a sufficient part of the shipment has been removed from the car to make it feasible, the loose explosives should be carefully swept up and destroyed. The danger of starting an explosion in a car of deflagrating explosives would lie principally in sparks or fire. In unloading a car of black powder or any other kind of explosives, some protection from sparks from passing engines should always be provided. Men should never smoke while handling explosives or when working in close proximity to them. This applies not only to unloading but to every stage of the handling of explosives in the course of transportation, distribution, and blasting. Cases or kegs containing explosives should always be lifted and set down carefully, never slid over one another, nor dropped from one level to another. Bale hooks or any other metal tools should never be used in handling explosives.

Vehicles. Any vehicle used to transport explosives should be substantial, strong, in first-class working condition, equipped with tight wooden floor, and either provided with sides and ends sufficiently high to prevent the explosives from falling off, or equipped with a closed body. All metal in the body

likely to come in contact with explosives packages should be covered with wood.

Trucks carrying explosives should be equipped with not less than two fire extinguishers in good order.

Explosives being transported in an open-bodied vehicle should be covered with a fire-resisting tarpaulin.

Vehicles transporting explosives should not be loaded beyond the manufacturer's rating.

In transporting explosives, congested traffic should be avoided, where possible, and no unnecessary stops made. Do not stop at a garage, or a repair or blacksmith shop for repairs when explosives are aboard if it can possibly be avoided.

The location of the batteries and the wiring on motor vehicles transporting explosives should be such that neither will come in contact with the explosives packages, and all wiring should be completely insulated and securely fastened, so as to prevent short-circuiting and fire.

To minimize fire hazard, motor trucks, engine, pan, chassis, and body should be kept clean and free from surplus oil and grease.

Motor trucks used for transporting explosives should be inspected daily in order to determine that the provisions of the two preceding paragraphs are complied with, and that the steering gear and brakes are in good condition.

Vehicles used for transporting explosives should carry signs or placards on each side and each end, with the word "EXPLOSIVES"—or display a red flag 24 in. square, marked with the word "DANGER" in white letters.

Do not smoke or permit smoking on a vehicle transporting explosives.

Metal, metal tools, carbide, oil, matches, firearms, electric storage batteries, inflammable substances, acids, and oxidizing or corrosive compounds should not be transported in a vehicle containing explosives.

STORAGE

The basic safety considerations are, of course, that storage magazines should be so located, so protected by natural or artificial barriers, so constructed, and so managed as to guard against accidental explosion of their contents, and to prevent injury to property or persons in case such an explosion does occur.

Explosives should not be left, kept, or stored where children, unauthorized persons, or animals have access to them; where

they are exposed to the direct rays of the sun; or in dwellings, offices, barns, outhouses, boiler rooms, blacksmith shops, or other shops, oil or tool houses, or tool boxes. Every year many children are injured, maimed, or killed by explosives or detonators which have been left where they can get them.

The conditions of storage of explosives have a much deeper relation to safety in their use than is commonly realized. Improper storage of explosives, detonators, fuse, and squibs leads directly to misfires, to incomplete detonation which leaves unexploded powder in the borehole or thrown out among the blasted material, and to the burning of charges in the borehole. Even a small leak in a magazine roof may allow a few cartridges of explosive to become wet, and the use of one of these cartridges for a primer may result in a misfire. A dilapidated magazine, or a magazine with floors close to wet ground, or any condition of storage which would expose ammonium nitrate explosives—and these include the permissibles and the "Extra" dynamites—or blasting caps, or safety fuse to moisture is almost sure to result in misfires. As the handling of misfires, and the existence of undiscovered misfires constitute two of the chief sources of accidents from explosives, measures to prevent misfires are fundamental to safety. One of the most important of these measures is to provide dry storage magazines.

Inadequate ventilation of magazines may also lead to accidents. Unless air circulates freely through a magazine the atmosphere may become hot and humid. Long exposure to such atmosphere has much the same ultimate effect upon ammonia explosives, blasting caps, and fuse as has dampness.

If a steel magazine is used without protection of some kind from the direct rays of the sun, there is danger that the metal will absorb so much heat as to cause the explosive inside to become hard and insensitive. Especially is this likely to happen in a climate of hot days and cold nights where the explosive is subjected to repeated alternations of high and low temperatures. Numerous instances are on record of misfires and partial detonations due to just this cause. A steel magazine in a region of hot sunshine should be protected by a wooden roof supported on posts so as to leave free circulation of air between it and the magazine, or by a coat of aluminum paint. A steel magazine is not recommended in any case for carload storage.

Any deterioration of an explosive or a detonator that results in incomplete detonation and a burning charge underground

may cause fatal accidents, for the gases given off by such shots are extremely poisonous.

For all these reasons, dry, well-ventilated, and reasonably cool magazines are essential to safety in the use of explosives.

Magazine Locations. In some states, the location of a magazine is restricted by laws and regulations (in cities by ordinances), and storage provided in such states should conform to state laws or local requirements. Where no such laws or regulations exist, it is recommended that magazines be located in compliance with the American Table of Distances (see Appendix), which specifies the quantity of explosives that may safely be stored at various distances from inhabited buildings, railways, and public highways.

Where there are two or more magazines on the same property, the following rule for their separation one from the other should apply:

POUNDS OF EXPLOSIVES	SEPARATION OF MAGAZINES
Over 50 and under 5,000	Detached from other structures.
Over 5,000 and under 25,000	200 ft.
Over 25,000	200 ft plus 2½ ft for each 1,000 lb additional.

These distances may be halved if hills or barricades are between buildings.

These distances between magazines are not required where the total quantity stored in the several magazines complies with the American Table of Distances as regards proximity to inhabited buildings, railways, and highways, except that magazines containing blasting caps or electric blasting caps should not be within less distance than 100 ft from any magazine other than detonator magazines.

A magazine location should be selected with a view, first to safety, and, second, to economy in operation. In a hilly, rolling country, the best locations are where the hills will afford protection; in a flat country, artificial barricades should be used or the specified unbarricaded distance provided. Natural features of the ground, such as dense woods or forests, if fire risk is not excessive, provide good protection and suitable locations for magazines.

Side hill dug-outs are not recommended as they are difficult to ventilate and usually wet.

Magazine sites should be chosen and cleared so that they are not endangered by forest or brush fires.

Storage of the daily requirements of explosives for any operation should be carefully considered and the magazines should be located so that in the event of an explosion there would not be serious damage to life or property; the quantity of explosives so stored should be kept at a minimum consistent with the operation and the risk involved.

Except when necessary, or when the American Table of Distances can be complied with, storage within city limits should be avoided.

Magazine Construction. For the permanent storage of high explosives the magazine should be bullet- and weather-proof, fire-protected, and sufficiently ventilated to protect the explosives properly in the specific locality. The foundation for such a magazine may be brick, concrete, or stone, and the magazine walls above the top of foundation or floor level should be of medium soft brick that will resist weather conditions and laid in cement mortar containing not more than 25% lime; or the magazine above the foundation may be of frame construction, sheathed outside and lined inside with not less than ⅞ in. tongue and groove boards, blind and face nailed with nail heads countersunk, the intervening space between the inner and outer lining from the sill to the plate completely filled with dry, sharp sand well tamped in. The thickness of the sand bullet-proofing should vary from 6 in. to 12 in. depending upon the caliber of rifle and kind of ammunition used in the locality.

The outside of the building should be fire-protected with not less than No. 26 gauge galvanized iron, firmly secured in the building with galvanized nails and lead washers.

The roof should be of wood frame and sheathing, covered with corrugated galvanized iron or tin. If galvanized metal is used, it should be secured with galvanized nails and lead washers. All woodwork on the outside of the magazine should be fire-protected with not less than No. 26 gauge flat galvanized iron. If explosives can be shot into through the roof, it should be bullet-proofed with sand. This can be done very readily by putting in ceiling joists at the plate line, as if a second story were to be built, laying on these joists a ⅞ in. tongue and groove floor with a 4 in. side, so as to form a shallow box, covering the floor, sides, and ends with building paper, and filling the tray with 4 in. of dry sand. If the explosives cannot be shot into through the roof, it should be ceiled to keep the magazine cool.

Sufficient ventilation in the foundation and roof should be provided to protect the explosives properly in the specific locality.

The floor, except in front of the door, and the bullet-proof sand box or ceiling should be set back at least 2 in. from the brick walls for ventilation.

The bullet-proof door should consist of not less than three thicknesses of $\frac{7}{8}$ in. matched hardwood boards, covered on the outside with a $\frac{3}{8}$ in. steel plate.

For the storage of black powder only, the magazine should be weather-proof and fire-protected. The foundation may be of brick, concrete, or stone. Above the foundation, the magazine may be of frame construction, sheathed with wood on the outside and covered with not less than No. 26 gauge galvanized iron firmly secured to the building with galvanized nails and lead washers.

The door for the black powder magazine may be built of two thicknesses of $\frac{7}{8}$ in. boards laid diagonally and covered on the outside with No. 22 gauge black or galvanized flat iron, allowing the metal covering to extend one inch over the sides, top, and bottom of the wood backing.

The roof should be of wood frame and sheathing covered with corrugated galvanized iron secured with galvanized nails and lead washers, and all woodwork on the outside of the magazine fire-protected with not less than No. 26 gauge galvanized flat iron.

If the storage magazine is to be only temporary, it may occasionally be found economical to use a post foundation. The outside sheathing and metal covering of the magazine should be extended about 6 in. into the ground for fire protection. Ventilation is provided by cutting holes about 6 in. by 6 in. through the sheathing, covering these with No. 6 gauge $\frac{3}{4}$ in. mesh wire screen secured to the sheathing, or by cutting or punching $\frac{3}{4}$ in. holes in the galvanized iron covering.

Where it is necessary to store small quantities of high explosives, either one of the two following types of magazines will be found useful. First, a box of the required dimensions built of 2 in. hardwood, completely covered with No. 24 gauge iron and provided with substantial hinges and lock. This may be placed on wheels if desired. Second, a double box, constructed as follows: each box being built of $\frac{7}{8}$ in. tongue and groove boards and the outer box being 1 ft longer, 1 ft wider, and 1 in. deeper than the other. Build the outer box like an ordinary contractor's tool box, with sloping hinged lid

Set one box in the other so that there will be a 5 in. space between the boxes, fasten them together, and fill the space with dry, coarse sand. Do not use gravel or stone. At the top of each box on the sides and end cut ¼ in. by 2 in. notches spaced about 1 ft apart but not directly opposite. Cover the outer box and lid with No. 24 gauge galvanized flat iron.

Complete plans for any of the preceding types of magazines may be secured from E. I. du Pont de Nemours & Company (Inc.), Storage and Delivery Section, Explosives Department, Wilmington, Delaware.

It is occasionally necessary to store daily requirements of explosives in cities. If the local ordinances or regulations do not specify the type of construction, it is good practice to construct such a magazine weather-proof and fire-protected; painted a distinctive color and conspicuously marked on the outside to indicate the contents.

In hot, sunny locations, every effort should be made to keep the magazine cool. Tree shade—aluminum paint on roof; or, in some cases, a false roof with air spaces between it and the real roof should help to reduce the temperature inside the magazine

Magazine Operations. The following are only a few of the principal points to be observed in connection with magazine operations:

Never store blasting caps or electric blasting caps in the same magazine with other explosives.

It is not a good or safe practice to store dynamite in a black powder magazine unless the magazine is bullet-proof.

Do not store inflammable materials, oil, paints, carbide, metal, metal tools, machinery, or any other material in a magazine with explosives.

Do not carry matches or permit matches to be carried in or around magazines, trucks, powder cars, or wagons containing explosives. If artificial light is necessary, use only electric flashlights or electric lanterns; do not use oil-burning or chemical lamps, lanterns, or candles in or around a magazine.

Do not smoke or permit smoking in or around magazines, trucks, powder cars, or wagons containing explosives.

Always use oldest stocks first. In receiving new consignments, arrange stocks so that the balance of the old stock will be readily accessible.

Cases of high explosives should be stored top side up; in other words, so that cartridges are lying flat and not standing on end.

Powder kegs may be stored on sides or ends. If stored on end, it is better to put the bungs down, and if stored on sides, to put the seams down, to assist in keeping the powder dry. To prevent the powder from caking, powder kegs should be shaken with the hands or rolled every thirty or sixty days.

Do not open or re-cooper packages of explosives in a magazine, nor prime cartridges, nor keep primed cartridges in a magazine.

Cases that have contained explosives should be destroyed by burning out of doors; do not burn them in a stove.

Empty black powder kegs should be disposed of by sinking them in a river or other large body of water.

Keep floors of magazines clean. Floors should be swept frequently and the sweepings removed and destroyed. Do not permit loose cartridges of explosives or loose caps to be in the magazine; keep them in boxes covered with lids.

In case magazine floors become stained with nitroglycerin, they should be scrubbed well with a stiff broom, hard brush, or mop, using a solution composed of 1½ qt of water, 3½ qt of denatured alcohol, 1 qt of acetone, and 1 lb of sodium sulfide (60% commercial). The liquid should be used freely to decompose the nitroglycerin thoroughly. If the magazine floor is covered with rubberoid or any material impervious to nitroglycerin, this portion of the floor should be thoroughly swept with dry sawdust and the sweepings taken to a safe distance from the magazine and destroyed.

In order to prevent brush fires from reaching magazines, trees should be kept trimmed back, grass, weeds, and underbrush should be kept cut, and the open ground around magazines kept free of dry leaves or other combustible rubbish

DISTRIBUTION

The transportation of explosives and detonators from the main storage magazine to the boreholes involves many problems of safety which vary with all the conditions peculiar to different kinds of work. Certain general principles will be stated here and then some of the ways and means of applying these principles in the chief kinds of work will be discussed.

First, explosives and detonators should be kept apart until the last possible moment. Whenever feasible, they should be transported in separate conveyances or be carried by different men. If both must be transported in the same conveyance, or be carried by the same man, they should be placed in separate insulated containers.

Second, high explosives and detonators should always be carefully and not roughly handled, protected against shock and friction.

Third, all explosives and detonators should be protected from fire, flame, or sparks.

Fourth, they should be protected from moisture.

Fifth, wires of electric detonators, if not short-circuited, should be kept from contact with stray electricity or electrically charged surfaces.

Operations Above Ground. In open work, much the same recommendations apply to transfer of explosives from the magazine to the scene of the blast as were made for transportation from the railroad car or other receiving point to the magazine. In this case, the route is usually through the operator's own property so that he himself is responsible for the condition of the road. It is the part of wisdom to provide good roads for wagons or trucks hauling explosives and to keep them clear. Likewise, where men carry the explosives, they should have a good, clean, even path.

In large open pit operations where locomotives and steam shovels are always at work, it is best to convey explosives to the working face in covered trucks or cars to protect them from sparks and hot cinders.

A dangerous practice to be avoided is delivering the entire load for a deep well drill hole or a sprung hole at one time. Fatal accidents have been caused by the fact that when a premature explosion occurred during the loading of a hole there were large quantities of dynamite stacked around the collar of the hole, and in one instance, at least, in close proximity to a reel of "Cordeau" extending into the hole, and that these were exploded by the premature detonation in the borehole. It is a good rule to deliver the proper number of cases of dynamite for each hole at a point at least 50 ft back of the hole, open them there, take one case up to the hole at a time and return the empty case and lining paper to a waste pile. In this way, the one case being loaded will be the only one near the collar of the hole at any time, and box covers with nails in them and slippery lining paper will not be strewn on the ground around the collar of the hole. Some blasters feel that still greater safety is gained by keeping this one case being loaded 6 ft back from the hole and having one man hand cartridges from it to the man who drops them in the borehole.

Underground Operations. In underground operations, distributing magazines are often necessary near the mouth of the mine. These should conform to the same general standards as main storage magazines. In particular, the same distributing magazine should never be used for both explosives and detonators, and the temptation arising from the convenient location of a distributing magazine to allow tools, carbide, oil, and other supplies to be kept in it should be rigorously guarded against. A distributing magazine should never contain more than one day's supply of either explosives or detonators.

Whether the operator provides haulage into the mine for explosives and detonators, or whether they are carried in by the men depends upon local conditions, but, whatever the system employed, it should be safeguarded as closely as possible. In the former case, explosives should be hauled in a covered, insulated powder car, or if covered, insulated boxes are provided to hold the miners' individual insulated containers, these boxes may be hauled in an ordinary mine car. Various satisfactory types of insulated powder cars are in use. The car may be built entirely of wood, the different sections being put together with wooden pegs instead of nails, or it may be of wood lined with sheet asbestos or rubber, or of metal lined with wood with all nails or screws countersunk so that there is no exposed metal whatever. The body of the car may consist of a single compartment for carrying explosives, or it may be divided into small compartments for the miners' individual powder boxes or bags.

Explosives and detonators may be hauled on separate trips, or detonators may be carried into the mine by shot-firers. A type of powder car being used today by some coal mines which seems reasonably safe has two separately insulated compartments—a larger one opening from the side of the car for explosives, and a smaller one opening from the end of the car for detonators.

The safest way to haul a powder car into the mine is to shut off all electric power and haul the car by mules. If the car is hauled by an electric motor with an overhead trolley, it should be separated from the motor by two or three empty cars so that sparks from the trolley cannot fall on it. It should be attached to the preceding car by an insulated coupling. The powder car should never be attached to the man trip, nor immediately precede nor follow it. If both are in motion at the same time, the air current should move from the man trip

toward the powder car. The best plan is either to send the powder car into the mine between shifts, or to have it precede the man trip by sufficient time to reach its destination before the man trip leaves the outside.

The powder car may deliver explosives and detonators to separate underground distributing magazines where these are permitted, or to the various sections of the mine, or, in case the men's individual containers are filled on the surface and hauled in the car, the men may claim these directly from the car at some central station underground. To facilitate this, each man's container should be marked with his check number. If underground distributing magazines are used, the two should be located at such a distance from each other that an explosion in the detonator magazine would not be communicated to the explosives magazine. Both magazines should be fireproof and be kept locked. They should be well ventilated and if lighted by electricity, wires should be enclosed in substantial grounded conduits, and lamps should be of the double bulb vapor-proof type. They should never contain more than one day's supply of explosives or detonators at a time, and they should be kept clear of all empty boxes, papers and refuse of any kind.

Miners should be equipped with non-conductive boxes or bags in which to carry explosives from an underground distributing magazine to their working places, and no explosive should be issued to a miner unless he brings such a container to receive it. If the miner does his own shooting, he should also have a separate, non-conductive container for detonators. If cap and fuse firing is used, it is well to have the magazine keeper crimp caps to fuses, dipping them in cap sealing compound, if necessary, and deliver the capped fuses to the miner. This applies especially to ore mines and other operations where the miner needs a number of caps and fuses of several different lengths for firing a round.

If shot-firers are employed, as in many coal mines, they usually carry the detonators into the mine—only the explosives being sent in by powder car—and should, of course, have non-conductive, waterproof containers. A very satisfactory type of container for electric detonators consists of a canvas belt with compartments for individual detonators which is folded and placed in a leather case with lock and carrying strap.

If explosives and detonators are not sent into the mine in special powder cars, it becomes necessary to provide safeguards for their transportation by miners and shot-firers. If the latter

are employed, they generally carry the detonators and the miners the explosives. Sometimes the shot-firers carry both explosives and detonators. If miners do their own shooting, they carry both. The same safety regulation should be enforced under all these conditions, namely, that explosives and detonators be carried in separate non-conductive cases. For men to carry blasting caps or electric blasting caps in their pockets is a not uncommon but highly dangerous practice. Every available means should be used to prevent it.

The next problem of safety that arises—and this applies particularly to coal mines—is what the miner shall do with explosives after they reach his working place and before they are loaded in the boreholes. Where the explosive is delivered in the case, probably the safest method is to open the case and place the cartridges in a wooden box provided for the purpose at a considerable distance from the face, and lock the box. Explosives taken into the working place in a carrying container can be locked up in such a box, container and all, or the container can be placed in a cubby hole cut in the rib or in the wall of a crosscut. If the miner has detonators, these should be locked up in a separate storage box or put in a cubby hole, either one being at least ten feet distant from the box or cubby hole for explosives. In a crosscut, the cubby hole for the explosives may be on one side and that for the detonators on the opposite side. All such cubby holes should be from six to ten feet distant from the track and from trolley wires. To leave explosives or detonators lying on the floor where they may be stepped upon, or run over, or struck with tools or may come in contact with electrical currents, is inexcusably careless and invites disaster.

The disposition of explosives and detonators left over at the end of a shift has a very important bearing on safety. Aside from the danger that if left in the mine they may be accidentally exploded as by a fall of rock, for example, there is also the hazard that explosives or detonators or electric squibs which have absorbed moisture from the mine atmosphere will cause misfires. If at all possible, left-over explosives, detonators and squibs should be taken out of the mine and stored in the proper magazine. If they must be left in the mine, they should be placed in a moisture-proof container and this locked up in a wooden box. Of course, explosives and detonators should never be left in the same container or in the same box.

A record should be kept at the distributing magazine of all explosives and detonators issued to miners and shot-firers.

Any powder or detonators left over at the end of the shift should be returned to the magazine at the end of the shift by miner or shot-firer, and this should be issued to him again on his next shift. If any part cartridges remain at the end of the day, they should be left in a moisture-proof container and used the next day.

OPENING CONTAINERS

Metallic Kegs. There is only one way to open kegs of black blasting powder properly and safely: the four metal clips on the bung should be pried up with a sharpened wooden stick and pressed back with the same implement or the fingers; and the metal cap and underlying paper washer should be lifted out with the fingers.

It is never safe to drive a hole in a powder keg even with a wooden pin. The use of any metal instrument, such as a pick or a rail spike, is definitely very dangerous.

Wooden Boxes. Fig. 37 (page 76) shows two methods for opening wooden boxes of explosives. The implements needed in both procedures are a sharp hardwood wedge and a mallet.

In method (A), which can be used on lock-corner boxes and is recommended particularly for boxes with nailed corners—plain, batten, or cleated, the lid is pried off. The box is stood on end and the lid is then loosened all the way across the top end by driving against the edge with the wooden wedge. When a crack has been obtained between the lid and the end of the box, the wedge is driven into the opening to widen it. Then the wedge is used as a pry to lift one end of the lid until the nails lose hold. The box is then placed flat and the lid raised until the handle of the mallet or wedge can be placed under the lid near the end where the nails still hold. With this as a fulcrum, the remaining nails can be lifted by pushing downward on the free end of the lid.

In method (B), which is quicker and easier for lock-corner boxes, the whole top of the box is split off. The procedure is as follows:

First, the box should be stood on end, the edge of the wedge placed on one corner at the third dovetail from the top. When the head of the wedge is struck a sharp blow with the mallet, a split will be started in the box from this corner. Next, the operation should be repeated on the opposite corner of the same end. This will usually carry the split around the

box so that a slight pull will remove the lid intact, with the strips of the sides and ends containing the nails attached. This method has the advantage of eliminating top boards with nails protruding.

Metal tools—chisels, screw drivers, hammers, or nail pullers—should not be used. Furthermore, it is not safe practice to cave in the lids with crushing blows or to burst cases open by dropping them on a corner.

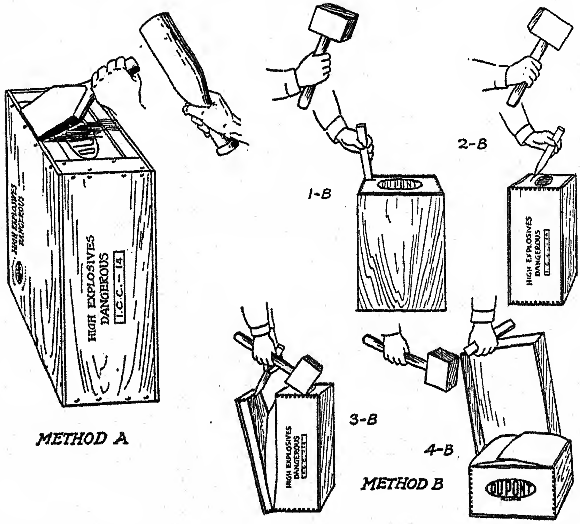


Fig. 37—Two methods recommended for opening cases of explosives

DESTROYING EXPLOSIVES

It is often necessary to destroy explosives. These explosives may be fresh material from containers which have been broken during transportation, or usable material for which there is no further need on a job, or they may consist of material which has deteriorated from one or more causes or which has become unfit for use through some sort of damage. Frequently, deteriorated explosives are much more hazardous than those in good condition and hence require special care in handling

and disposal. The methods recommended for destroying various explosive products are given in the following paragraphs. If large quantities of explosives must be destroyed, if experienced or competent men are not available for the work, or if there is any question in one's mind about the safety of the undertaking, then the handling and destruction of the explosives should be deferred until a representative of an explosives manufacturer has been consulted.

Black Powder. This is best destroyed by pouring the powder into a river or large body of water. Pellet powder should be removed from its wrappers to insure quick destruction.

Dynamite. When properly stored and cared for, dynamite will remain in good condition for years, but it will deteriorate rapidly if improperly treated. Dynamite which shows obvious signs of deterioration, such as hardness, discoloration, excessive softness, or leakiness, should be destroyed. In addition to deterioration from prolonged or improper storage, dynamite may also become unfit for use through some damage, such as wetting, and this should also be destroyed.

Small amounts of dynamite can be destroyed by exploding them in a safe place, but this is not usually practical where larger quantities are involved. The most satisfactory method of destroying dynamite is by burning, which can be done safely, providing certain precautions are taken.

First of all, it must be assumed that there is always a possibility that the burning dynamite may explode. Consequently, the most important consideration in burning dynamite is to choose a safe place, far enough away from any dwelling, railroad, highway, or any place where people may assemble so that if an explosion does occur, no injury to persons or damage to property is possible. It is also advisable to limit the amount of dynamite burned at any one time, preferably to not more than 100 lb. An exception to this is the permissible gelatin dynamite "Gelobel" which is particularly prone to detonate upon being destroyed by burning, so that not more than 10 lb should be destroyed at any one time.

Dynamite should never be burned in cases or in deep piles. The cases should be opened, using special care if there are any signs of leakiness, and the cartridges removed, slit, and spread over the ground, preferably with a mat of loose paper or excelsior beneath. Some dynamites do not burn readily, hence it is necessary to have a combustible fuel beneath the cartridges. If the dynamite is wet and does not burn readily

even under these conditions, a little kerosene may be poured over it. The pile to be burned should be ignited by a small pilot fire of paper, wood shavings, or other kindling material placed close enough to the pile so that the flame will ignite the dynamite or the combustibles beneath it. After lighting the pilot fire, all persons should retire immediately to a safe distance until the dynamite has completely burned.

When more than 100 lb must be destroyed, a new space should be selected for each lot, for it is not safe to place dynamite on the hot ground of the preceding burning. As soon as all the dynamite has been burned, the ground where the material was destroyed should be plowed.

"Nitramon" and "Nitramon" S. The simplest way to destroy "Nitramon" and "Nitramon" S is to chop the cans open with a hatchet or axe, and empty the contents into a large body of water. If a lake or stream is not convenient, the "Nitramon" may be dissolved in water and emptied into a pit or spread over a surface of the ground and preferably covered by earth.

"Nitramon" Primers. Primers for "Nitramon" and "Nitramon" S contain a high explosive and cannot be destroyed by water. The best method of disposal is to shoot them singly in some suitable safe place, either under water, or covered by sand or earth, or in the open if there is no objection to the latter. If it is inconvenient or impossible to dispose of primers by shooting them, it is suggested that the problem be referred to a du Pont representative.

Detonators. Blasting caps, electric blasting caps, or delay electric blasting caps which have deteriorated from age or improper storage so that they are unfit for use should be destroyed. These should also be destroyed if they have ever been wet, whether or not they have subsequently dried out. The preferred method of destroying detonators is to throw them into deep water in the ocean or in the middle of a large lake. If this is impracticable, the only safe and effective method of destroying them is to explode them with dynamite. Detonators should not be thrown into small bodies of water, such as rivers, creeks, ponds, or wells.

If possible, it is advisable to destroy ordinary blasting caps in the original tin container with the cover removed, otherwise they should be placed in a small box or bag. A hole should be dug in the ground, preferably in dry sand, and at

least a foot deep. The box or bag is placed in the bottom of the hole and primed with a half-stick of dynamite and a good electric blasting cap or ordinary cap and fuse. The caps and primed cartridge should be covered carefully with paper and then with dry sand or fine dirt and fired from a safe distance. It is recommended that never more than one hundred caps be fired at a time and that the ground around the shots be thoroughly examined to make certain that no unexploded caps remain. The same hole should not be used for successive shots unless the entire inside surface of the hole feels cool to the touch.

To destroy electric blasting caps it is necessary first to cut the wires off about one inch from the top of the cap, preferably with a pair of tin snips. No attempt should be made to cut wires from more than one cap at a time. The caps should be placed in a box or paper bag, primed with a cartridge or half cartridge of dynamite and a good electric blasting cap, buried under paper and sand or dirt, and exploded as described in the paragraph above, observing the same precautions as have already been mentioned.

PERSONNEL

In addition to all the preceding detail in regard to the safest type of explosives and blasting accessories and the safest methods of handling them in the various kinds of work, there remain three fundamental principles for avoiding accidents that apply to every kind of blasting operation.

The first of these three principles is that the fewer men there are handling explosives the fewer will be the risks of accident. This means division of labor and systematizing of operations. It means that main magazines and distributing magazines will each have one man in charge and that no one else will be allowed to receive or issue explosives or detonators. In coal mining, it means the employment of shot-firers wherever feasible. In quarrying, tunneling, and similar operations where a crew of men work together, it means a definite assignment of the several tasks of carrying explosives and detonators, opening cases, loading, priming, tamping, connecting blasting circuits, and firing so that the entire crew will know exactly what each man's duties are, and everything will be done in a precise and orderly manner with no unnecessary men about and with no haphazard assumption of the various tasks to be performed. It is also desirable that persons other

than the loading crew should be kept away from the vicinity of the holes and the dynamite.

The second principle is that the men who do handle explosives should possess certain characteristics and knowledge and experience. They should be picked for intelligence and good sense and they should understand explosives—what is safe to do with them and what is dangerous—a kind of knowledge that can be gained only by experience. There are many men employed in mining, quarrying, and other blasting operations who have the requisite knowledge and good judgment, men who habitually handle explosives with skill and discretion, but others must be constantly trained. An absolutely green man should always be given definite instructions before he is allowed to handle explosives at all, and then should work under the supervision of a careful, experienced man until he demonstrates that he can be relied upon not to endanger himself or his fellow workers. Men who are in the habit of using explosives but who, through ignorance or carelessness or bravado, follow unsafe practices constitute the greatest problem. If the man is careless to the point of recklessness and unwillingness to mend his ways, the sooner he is removed from all contact with explosives, the safer; but for the training of the others many schemes are in successful use, some adapted to one operation, some to another. Among these, are the posting of safety regulations and of large scale, easily grasped illustrations of safe methods, at distributing magazines, change houses, mine and tunnel entrances and other places where men congregate; the distribution of bulletins—generally most helpful if illustrated—to men who can learn from the printed page; the holding at regular intervals of safety meetings and blasters' schools in which a definite and progressive program of education is carried on through talks by officials or others equipped to give instruction, through motion pictures, and perhaps most important, through question and free discussion among the men themselves; and the direct day-by-day instruction of the man at work by his immediate superior.

One of the most important services given by explosives manufacturers to the consumers of their products is the sending of technically trained field men into every kind of blasting operation to show the men on the work the safest and most efficient blasting practices. The explosives companies, the United States Bureau of Mines, and the National Safety Council all issue valuable bulletins describing safe and dangerous practices, but these are necessarily somewhat general. The

superintendent and safety engineer can, and should, go a step farther than this. They should make a periodical survey of the entire operation of which they have charge to determine all the hazards that exist under the specific local conditions, and then should devise ways and means to remove the unnecessary hazards and to train the men to avoid accidents from the hazards that cannot be eliminated.

The third general principal is that safety regulations must be enforced. Men must not only be taught safe practices but they must be required to use them. This means that close supervision and strict discipline must be maintained—not nagging supervision and harsh discipline, but continuous friendly and helpful oversight with impartial application of penalties for violations of rules and quick recognition, with or without appropriate awards, of care in observing them. Much can be accomplished by fostering among the men a group spirit of responsibility for safety, and by encouraging friendly competition between individuals and between groups for the reduction of accidents.

CHAPTER VII

PREPARING BLAST HOLES

In this handbook blast holes are considered as including all types of openings or cavities into which charges of explosives are loaded for blasting. These may be shallow holes punched in soil or drilled by hand into a boulder or they may be deep well drill holes, or even tunnels many feet long in quarries. To provide the great variety of holes needed for different conditions of blasting requires the use of many types of drills, punches, and other devices. Preparing blast holes for loading also may require scraping, bailing if filled with water or mud, springing or otherwise enlarging, or casing if there is a tendency for them to become obstructed.

Proper placement of holes is an essential factor in their preparation and this is discussed in later chapters dealing with blasting in specific types of operations.

SMALL DIAMETER BOREHOLES

Coal Augers and Drills. Formerly drilling in coal mines was done chiefly by hand and the coal auger still finds considerable

Fig. 38—A hand-held electric coal drill

use. This is an adaptation of the brace and bit. Over all, it is usually from 6 to 7 ft long, the worm or twist being from 4 to 5 ft long. The brace or handle is attached to the worm by means of a collar and is held in position for drilling by a breast plate which is slipped over the end of the brace and is so constructed that it fits snugly against the body of the driller.

However, in recent years, the general trend toward mechanization of the coal mines has led to the widespread adoption of power drills. These are of either the compressed air or electric type, the latter being preferred where electric power

Fig. 39—A post-mounted electric coal drill

is available. The electric drills in use are of several different types. There are hand drills which are held in position by the driller and which require one or two men for each drill; drills equipped with a post mounting which can be operated by a single man; drills mounted upon cutting machines so that they can be turned at any angle; and drills mounted on self-tramming, mobile trucks. Trucks are equipped with one or two drills, each mounted on a movable arm to permit drilling bottom, center or top holes at any angle.

Churn Drill. A churn drill made of a solid piece of drill steel from ⅞ to 1½ in. in diameter or of a drill bit on to the shank of which a gas pipe is shrunk is effective for putting down

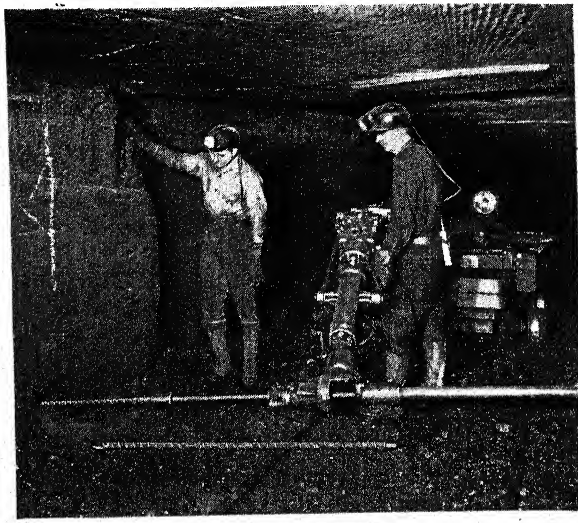


Fig 40 - A track-mounted, self-tramming mobile coal drilling unit

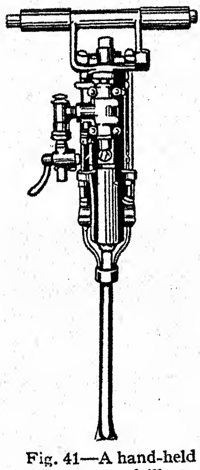


Fig. 41—A hand-held hammer drill

deep holes in all classes of material. The drill should be long enough to give it the necessary weight and to reach to the bottoms of deep holes. It is operated by hand, being lifted up and dropped back into the hole. The hole must be kept partly filled with water while the drilling is in progress. The bit or cutting edge of the churn drill is similar to that of the hand drill.

Hammer Drill. This drill, which is usually operated by compressed air, is most serviceable for drilling holes up to 10 ft in depth, and finds ready use in all kinds of rock blasting from railroad cuts, shafts, tunnels and similar heavy work, to blasting field and road boulders. The drill is comparatively light and easily carried. The required air is furnished by

a portable compressor when a stationary compressor outfit is not convenient. Hammer drills have largely replaced the older piston-type drills.

Drifter Drills. A slight modification of the mounting permits the hammer or piston drill to be mounted on a vertical column or horizontal bar in a tunnel. This permits rapid drilling, and is much used in tunneling and mining operations.

Column mounting requires that some muck be removed at the face before the drills can be set up. Horizontal mounting

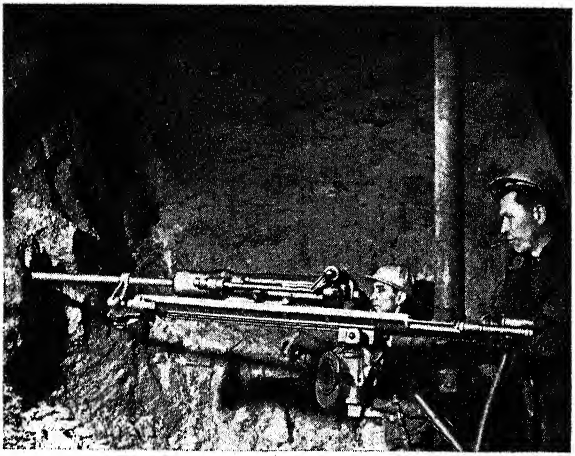


Fig. 42—A column-mounted drifter drill

has the advantage that drills can be set up over muck. Both types of mounting make it possible to carry on drilling and mucking more or less simultaneously.

Drill Carriages. In recent years tunneling operations have made good use of the drill carriage or "Jumbo" mounting. The drill mounting consists of a heavy framework for carrying the columns, arms, and bars for mounting two or more drills. Up to 35 drills have been mounted on the largest carriage. The carriage also comprises platforms for the drillers to stand on, usually designed to drop to the side when not in use; facilities for carrying drill steel, bits, and tools; manifolds attached to the main air and water lines and providing outlets for each drill; and finally headlights or flood lights to illuminate the working face.

Drill carriages may be built on trucks to run on rails or on self-tramming caterpillar crawlers or may be mounted on the bed or chassis of a motor truck.

The drill carriage enables a lot of equipment to be moved to the heading quickly; provides all the scaffolding and mountings for as many drills as can be operated simultaneously; eliminates most of the setting up of drills and connecting up of lines; facilitates drilling and loading holes with explosives in many ways; and lastly permits the equipment to be removed readily and quickly when drilling is finished.

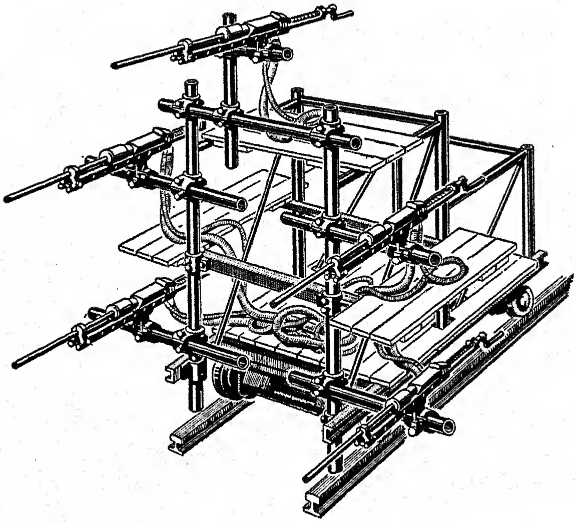


Fig. 43—A drill carriage

Drill carriages can only be used in front of a cleaned up face so that drilling and mucking cannot be done simultaneously.

Stoper Drills. These are special hammer drills used for overhead drilling, as in raising and in overhand stoping.

Stopers require no separate mounting since they stand on a telescoping air leg. The air leg not only serves as support but is also the feed mechanism.

Fig. 44—Stoper drills at work

Tripod Drills. These both the piston and hammer type, find their readiest use in heavier work than that to which the light hammer drill is suited. They drill larger holes, from 1 to 3 in. in diameter, can work to greater depths, and even under water. Either steam or compressed air can be used to furnish the power. Recent improvements in the tripod hammer drill have produced high-speed drills of great efficiency, which can drill either vertical or horizontal holes 30 ft deep. The chief use of tripod drills is in quarries, railroad and canal construction, heavy cuts, and similar work.

Fig. 45—A tripod drill

Wagon Drills. During recent years wagon drills have come into wide use. The wagon drill mounting consists of a light steel frame and derrick or tower on three wheels either all steel or with pneumatic tires, also with steel skids. Various type drills, principally hammer drills, can be mounted on the tower. The whole machine is easily moved by hand. In some types the tower can be tipped to permit drilling holes at angles other than vertical. Holes up to 4 in. in diameter and 40 ft in depth can be drilled with steel changes of 6 ft to 10 ft.

Some drills are equipped with air motors and automatic feed. In larger types for down holes up to 40 ft deep, the drill is fed down by its own weight plus a slab back with adjustable weights. Drill can be raised by hand or air hoist. Speeds from 25 ft to 70 ft per hour are possible depending on hardness of rock, depth and size of holes and air pressure carried.

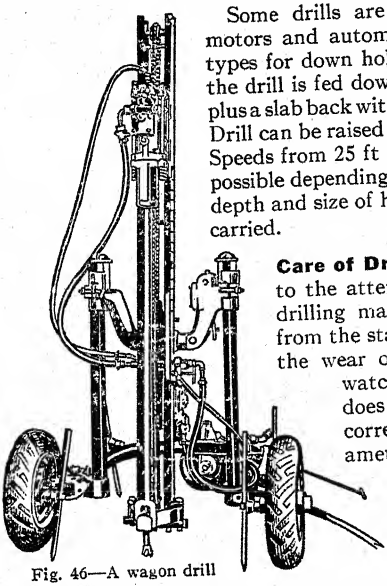


Fig. 46—A wagon drill

Care of Drill Bits. In addition to the attention that drills and drilling machinery should have from the standpoint of efficiency the wear on the bit should be watched so that the gauge does not fall below the size corresponding to the diameter of the dynamite cartridges. A lazy drill runner will frequently allow his drill bit corners to wear to such an extent that the dynamite cannot be placed in the bottom of the borehole or can only be rammed down with difficulty. This is likely to cut down the useful work of the explosive and is always dangerous.

Detachable Rock Drill Bits. There has been a widely increased use of detachable bits in recent years. They are furnished by various steel and drill manufacturers. Bit gauges vary from 1¼ in. to 4 in. in diameter. The four-point bit is most common although other patterns are available. Bits are secured to drill rod by means of a thread and are easily changed. They have proved to be more economical and efficient than the conventional type of drill steel and bit in many operations.

Diamond Drills. The diamond core drill was originally built for exploratory drilling but has recently been adapted to drilling long boreholes. For boreholes, core recovery is generally unnecessary so that the principal modification of the original exploratory equipment has been the introduction of non-coring bits. Coring equipment does perform better in some ground,

however, and can be used to obtain a record of the ground drilled through, but it is somewhat slower because of the necessity of pulling rods to empty core barrels.

Two sizes of equipment drilling $1\frac{3}{16}$ in. or $1\frac{1}{2}$ in. diameter holes are ordinarily used. The depths to which holes can be drilled is practically unlimited. The drills are usually powered by compressed air motors.

Fig. 47—A diamond core drill

Wood Auger. The Red Top Stump Auger with a crank is a ball-bearing auger that greatly reduces the labor involved in blasting tap-rooted stumps. Placing the left hand on the knob and the right hand on the crank handle and working from the side, using both hands in a circular motion, the operator can bore a hole into a stump at a surprisingly rapid rate and with relatively little exertion. The twist of the bit is 18 in. long and $1\frac{1}{2}$ in. in diameter. Over-all, the auger measures 6 ft in length.

There is also a Red Top Stump Auger with a wooden handle. This auger is made in $1\frac{1}{2}$-in., $1\frac{3}{4}$-in., and 2-in. diameters with 16-in. twist. The length of auger is $4\frac{1}{2}$ ft.

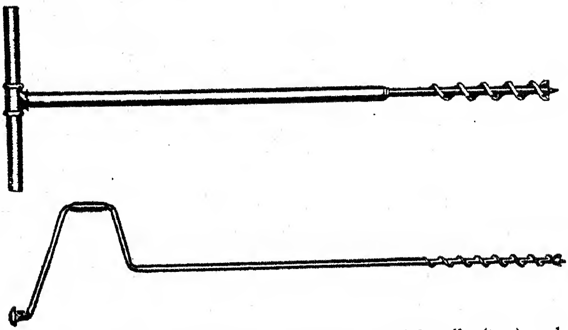


Fig. 48—A Red Top Stump Auger with rigid handle (top) and with ball bearing crank handle (bottom)

Soil Auger. For making boreholes and test holes and deepening other holes in clay, a soil auger is useful.

The Red Top Soil Auger consists of a bit 12 in. long with a twist 1¾ in. in diameter and a shaft and handle of 1-in.

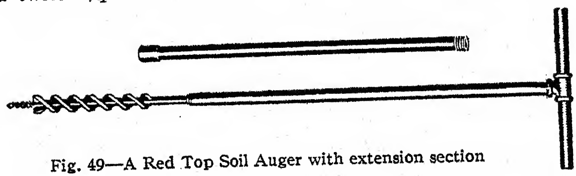


Fig. 49—A Red Top Soil Auger with extension section

pipe, giving a length over-all of 5 ft. An extension shaft 3 ft long may be added if desired.

This auger is always used by hand. When dry soil does not stick to the twist of the auger and falls back into the borehole, a little water poured into the hole will quickly overcome the difficulty.

Fig. 50—A soil punch or drill for making boreholes in soft material

Soil Punch. For shallow holes in clay, soft shale and hardpan the soil punch made of 1½-in. round or hexagonal tool steel drawn at one end to a pencil point is most serviceable. This

should seldom be longer than 4 ft. It is driven into the ground with sledges and loosened by pounding on the side. In extreme cases it can be drawn up by means of a chain and lever. It is suitable for making boreholes for cuts in hard ground, for pole hole blasts, for ditching and for almost all kinds of agricultural blasting.

The Red Top Punch Bar is fitted with a pipe handle which makes it easier to drive in and pull out and with an adjustable gauge which is very useful for measuring the depth of the hole

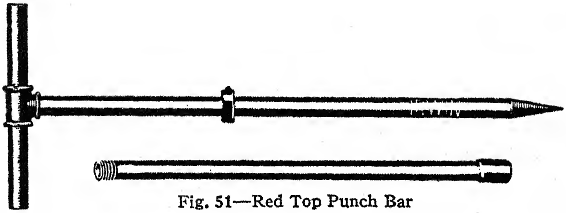


Fig. 51—Red Top Punch Bar

This punch bar and the other Red Top boring tools described herein are manufactured by The Irwin Auger Bit Company, of Wilmington, Ohio, for The Red Top Auger Co., Inc., of Birmingham, Alabama, and can be secured from either of the firms or through the Explosives Department of the du Pont Company, Wilmington, Delaware.

Ashley Core Punch Bar. In blasting ditches in wet soils, it is essential to make a hole in the soil to receive dynamite cartridges. An ordinary bar is used to make such holes. In many cases, the soil is of a sandy nature and the hole fills up as soon as the ordinary bar is removed. Some time ago, a core punch bar was developed, and has been in use for some ten years. This consisted of a shell with a core bar pinned inside of the shell. The two were pushed as far as possible into the ground, then the core was removed, and the dynamite cartridges loaded through the shell. The main drawback to the use of this tool was the inability of the operator to push it deep enough into sandy soils.

The Ashley Core Punch Bar applies the principle of a pile driver to the old-type core punch bar by having a weighted ring of metal and handles attached to the core in such a manner that it can be lifted and dropped inside the shell, thereby driving the bar as well as the core to any desired depth.

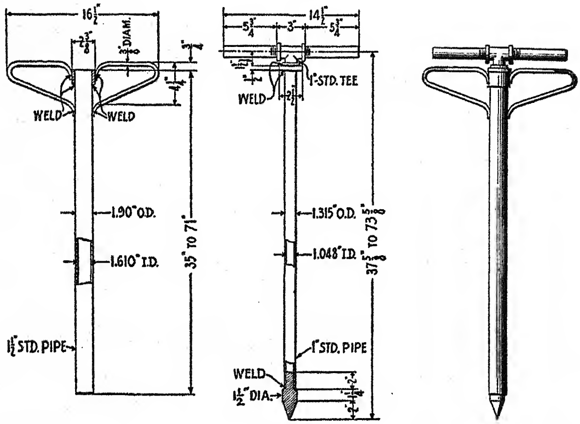


Fig. 52—Ashley Core Punch Bar and construction details

There are several variations in the type of point on the core and the depth of bottom on the shell. The use of these variations depends on whether one is working in pure sand or in gravel.

The use of this tool has added greatly to the efficiency of the loading and drilling crew when blasting ditches. It has also been found that due to the pile driving feature, this tool can be very effectively used in placing dynamite under obstructions such as stumps, boulders, etc., where the soil is of a wet, sandy nature.

The metal core should never be used to push dynamite through the shell. Several fatal accidents have been caused by this practice. Always use a wooden stick.

LARGE BLAST HOLES

Well Drills. These machines find their chief use in quarries, railroad and canal construction, pits and cuts where high faces or ledges are to be blasted down. Well drills are not ordinarily economical in faces less than 30 ft high. They drill holes from 4 to 12 in. in diameter, 5⅝ in. in diameter being the most common, and to almost any required depth. They utilize the churn drill principle and can be used for vertical holes only. They may be operated by steam, electric, or gasoline power.

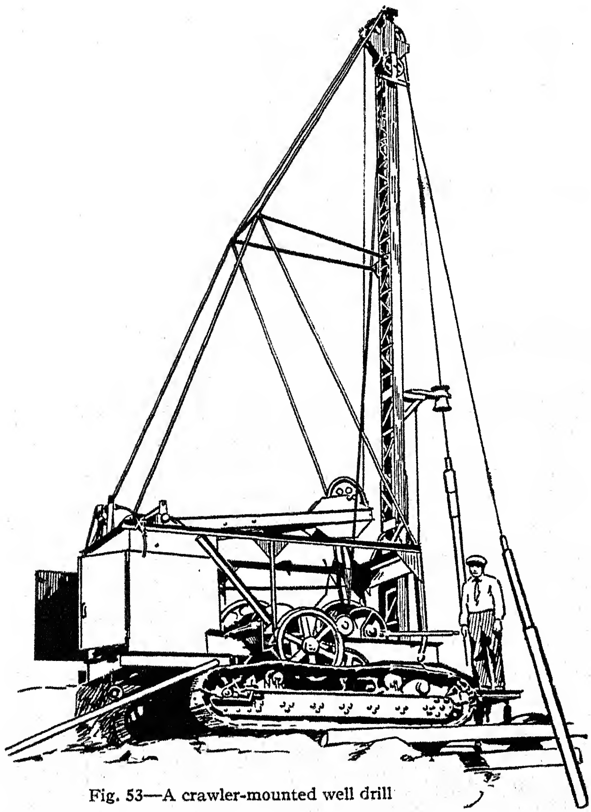


Fig. 53—A crawler-mounted well drill

On account of the large diameter of well drill holes they can be spaced farther apart than smaller holes and at greater distances back from the face. The depth and large diameter of well drill holes allow the explosive to be distributed to the best advantage and often permit the use of a lower strength explosive for a top load, above the stronger explosive necessary to pull the bottom and toe clean to grade. While one object of the large diameter of well drill holes is to do away with the

necessity of springing, occasionally in soft materials, where springing is easy, it is advantageous to space the holes farther apart and spring the bottoms.

Horizontal Drills. These have been used successfully in coal stripping. They are of the rotary auger type and bore holes from 4 to 6 in. in diameter and up to 50 or more ft in length.

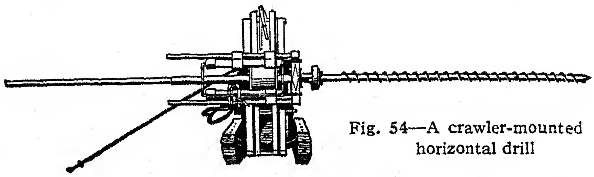


Fig. 54—A crawler-mounted horizontal drill

They are mounted on crawlers, either gasoline or electrically driven. In some formations without too heavy an overburden they effect a considerable economy in explosives. They are not adapted to drilling hard rock but in the soft shale stratum, over the coal, they are very effective.

Rotary Drills. The rotary well drill has been adapted to the unusual requirements of drilling for seismic prospecting. This type of drilling requires equipment that is portable, easy to set up and take down, and which will drill shallow or deep holes, ordinarily 40 to 250 ft, of 2 to 5 in. diameter, as rapidly as possible. As the drilling is usually in earth or relatively soft weathered materials, the rotary type is admirably suited.

The drilling rig or tower is mounted on a motor truck. When not in use or when being moved from one location to another, the rig is in a lowered position lengthwise on the truck and extending forward over the cab. The base of the rig is mounted on the end of the truck in a heavy swivel and balanced so that it can be raised to the vertical drilling position quickly and with little effort. In the vertical position the rig rests partly on the truck mounting and partly on spuds extending to the ground. As soon as the rig is raised, the drilling tool is inserted and drilling proceeds. Power is supplied for the rotary driving mechanism through the truck transmission from the motor. Ten-foot extensions are added as drilling progresses until the hole is driven to the desired depth.

Fig. 55—A rotary drill mounted on a motor truck

Pumps and Spoons for Cleaning Boreholes. In drilling downwardly inclined holes, water is used to lubricate the hole producing a mud with the spoil made by the drill bit. To facilitate drilling, this mud must be removed from time to

Fig. 56—A bailer for removing mud and water from deep well drill holes

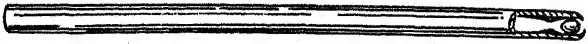


Fig. 57—One type of spoon for shallow boreholes which is a modification of the bailer

time. In deep vertical holes a pump, sometimes called a sand bucket, is used, while in slanting, shallower holes a spoon is used.

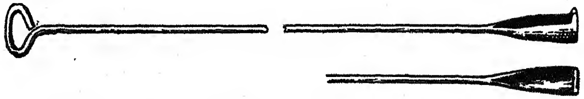


Fig. 58—Another type of spoon or scraper for shallow boreholes

Springing Boreholes. Boreholes are frequently sprung or chambered with dynamite, especially if they are to be charged with blasting powder or other bulky explosives. This makes it possible to keep the charge well down in the bottom of the borehole, where it is generally most needed, and also to place the required quantity of explosives in the borehole.

A borehole is sprung or chambered by exploding in the bottom several charges of dynamite, one after the other. The first charge usually consists of one or two cartridges, this being increased in subsequent charges until the chamber is sufficiently large to hold the requisite quantity of explosives. In a borehole smaller than 2½ in. in diameter, not more than six or eight 1¼ x 8 in. cartridges of dynamite should be exploded at one time, because heavier charges may cause the borehole to cave and close up. Slight caving often occurs with light charges, but the borehole can usually be opened with the drill or a steel bar. The explosion of each chambering charge increases the borehole slightly in depth and in diameter at the bottom. After a little experience the approximate size of the cavity can be estimated by noting the increase in depth by dropping a short bar of wood attached to a rope.

It is well to use a little dry sand or, in some cases, a little water for tamping the springing shots as it results in better execution.

The number of chambering shots necessary depends on the hardness of the rock and the size of chamber desired. In solid rock the chamber or cavity is the result of the dynamite explosion's burning or grinding off and forcing out through the borehole small spalls and fine particles of the rock, and is

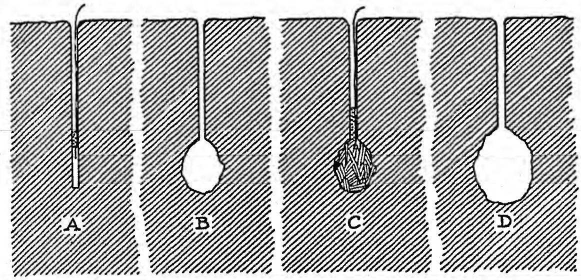


Fig. 59—Process of springing a borehole. A shows a single cartridge (2 or 3 can be used) in position for the first springing shot in a borehole of small diameter. B shows the result of the first shot. C shows the second charge in place. D shows the result of the second shot. Additional shots are made until the chamber is enlarged to the desired size

not the result of compressing the surrounding rock walls. Therefore, a quick-acting dynamite generally gives the best results in springing, because its effect is partly expended in shooting out of the borehole the material which it first pulverizes. The powerful and quick-acting dynamites are not as likely to cause caving and closing of the boreholes as are the slower-acting ones. Du Pont Special Gelatin 40% to 75% strength will usually be found most satisfactory for the work, especially from the safety standpoint. The quantity of this explosive required for chambering cavities of any given size depends upon the rock, but may be roughly estimated by allowing from three to six 1¼ x 8 in. cartridges (1½ to 3 lb) for each 25 lb of blasting powder the chamber is to hold.

In soft, clayey or similar ground the action of the springing charge is to pack the loosened material into the walls and thus enlarge the chamber. For such ground almost any fairly quick-acting dynamite will serve.

It is absolutely necessary, in order to avoid accident, that ample time be given the borehole to cool off after each springing shot and before charging it with blasting powder or any other explosive. Many serious injuries have been caused by lack of attention to this rule. Just how much time should be allowed is governed by the quantity and the kind of dynamite used for springing, and the number and frequency of the springing charges, and the character and condition of the rock, but under no circumstances should an attempt be made to load a borehole within less than two hours after the explosion of

the last springing charge, and it is better to wait four or five hours unless the hole fills with water. The possibility that a springing charge will heat the rock enough to explode the detonator in a subsequent springing charge must also be taken into account, and the blaster should always stand as far back from the mouth of the borehole as possible when loading any of the springing charges after the first one. Never spring a hole adjacent to a loaded sprung hole.

When a borehole is tested with a thermometer after springing, we recommend that no explosive be introduced unless a reading of less than 80° F. is obtained.

Tunnels for Blasts. These tunnels are sometimes called coyote holes. In some instances, it is desirable to concentrate large charges of explosives under the rock in blasting down a large tonnage of material. This is especially true in quarries, open pit mines, and heavy side hill cuts, where the nature of the rock is such that it is impossible to shape perpendicular faces, the face always assuming a decided slope; or where the stratification of the rock makes well drilling difficult and expensive; or where small but deep drill holes cannot be sprung. This method of loading overcomes these troubles and, in many kinds of stone, such as jetty stone, is an ideal method of loading for breaking down large fragments. The tunnels are usually horizontal, about 3 by 4 ft in section, and are driven in much the same manner as standard tunnels, except that the depth of drill holes and the number of holes in a round are less.

Gopher Holes. This refers to a hole of large diameter driven at the bottom of a face of rock similar to a tunnel adit except usually it is too small to permit men to enter. The hole is deepened progressively by drilling and shooting small holes and scraping out the broken material, all operations being done from the outside. Explosives are loaded in the back of the gopher hole and securely stemmed. This type of hole is used in quarrying and open pit mining to relieve heavy toe burdens.

In softer material short flat holes of large diameter approximating gopher holes are often made by the use of a long chisel-pointed bar and a long-handled spoon or hoe.

CHAPTER VIII

PRIMING EXPLOSIVES

A primer is a cartridge of explosive with some means of firing it attached. It is placed in the borehole along with the remainder of the charge and when fired explodes the latter. Both the method of making up primers and the location of the primer cartridge in the loaded boreholes vary with the kind of explosive used, the type of igniter or detonator used, and with certain conditions of blasting.

This chapter describes the recommended methods of assembling primers and of priming charges. Experience has indicated that these methods best fulfill the many essential requirements of properly made primers and correct priming.

MAKING UP PRIMERS

Primers should be carefully made so that they satisfy the following conditions:

(1) That the igniter or detonator cannot be pulled out of the primer cartridge.

(2) That the igniter or detonator be in the safest and most effective position in the primer cartridge.

(3) That the fuse or the wires of electric firing devices are not subject to harmful strains.

(4) That the primer is waterproof if necessary.

(5) That the whole primer assembly can be loaded safely, easily, and in the preferred position in the charge.

Detonators should be completely centered and parallel with the long axis of the cartridge. Dynamite cartridges used for primers should not be slit as the whole cartridge is necessary to hold the detonator in proper position and to protect it from abrasion or blows during loading. Sharp bends in fuse or tight knots in leg wires should be avoided. Openings in primer cartridges should be sealed with soft soap or wax if black powder or dynamite that is poorly water resistant is used in wet holes.

All the various methods of making up dynamite primers require punching one or two holes through the primer cartridge for the insertion of caps, leg wires or "Primacord." It is essential for proper punching that a satisfactory tool be used. The recommended dynamite punch consists of a pointed pin of wood, brass, aluminum, or other non-sparking metal and a wooden handle. The pin should be long enough to punch a hole at least a half inch deeper than the longest detonator used or through large diameter cartridges to permit priming by the recommended methods, and of sufficient diameter to provide for easy insertion of caps or wires. For small diameter primers made up by inserting caps in the side of the cartridge a curved pin is preferred so that the hole enters the side and curves toward the axis of the cartridge. The punch on the Du Pont No. 2 Hand Crimper is good for this purpose.

Black Powder Primers with Safety Fuse. A properly made primer of black blasting powder, illustrated in Figure 60, is made up as follows: A single knot is tied in the end of the fuse and several notches are cut in it about 2 in. apart starting near the knot; the knotted and gashed end is placed into a cartridge about one-third filled with powder; then the cartridge is filled to within about 2 in. of the top and closed by twisting and tying the paper around the fuse. This primer fulfills two essential requirements: ignition is insured by notching the fuse to obtain flame at several points; and the assembly is secure because the knot in the fuse prevents it from being easily pulled out.

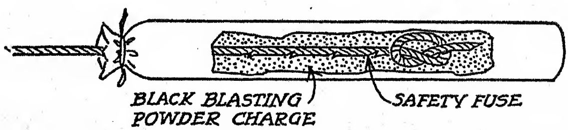


Fig. 60—The recommended method of making up a primer with black blasting powder and safety fuse

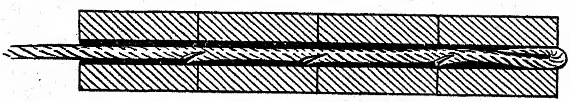


Fig. 61—The recommended method of making up a primer with pellet powder and safety fuse

The best primer with pellet powder and safety fuse, illustrated in Figure 61, is made up as follows: The fuse is cut on a long bevel, pulled through the cartridge, and gashed in three or four places about 2 in. apart starting near the end; the beveled end is doubled back toward the uncut side, so as to open the gashes, and inserted back into the center hole of the cartridge; and finally the fuse is pulled back until the doubled end tightens and holds fast.

This method provides for ignition from the gashes as well as from the end of the fuse and prevents the fuse from being pulled out of the cartridge during loading. It is poor practice to tie a knot in the end of the fuse, as this separates the primer from the next cartridge and leaves a space between for drill cuttings to collect.

Black Powder Primers with Electric Squibs. To make up a primer with black blasting powder and an electric squib, as in Figure 62, the cartridge is half filled with powder, the electric squib is inserted in the center, the remainder of the cartridge is filled with powder above the squib and around the wires, leaving enough empty shell at the top to twist and tie securely around the wires.

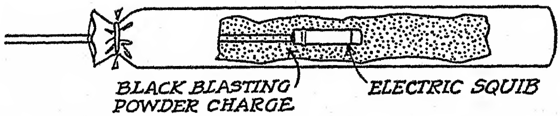


Fig. 62—The recommended method of making up a primer with black blasting powder and an electric squib

To make up a primer with pellet powder and an electric squib, as illustrated in Figure 63, holes are punched in both ends of the cartridge; the squib is pushed all the way through, pulled out about one foot and inserted in the opposite end; and finally, the wires are pulled tight.

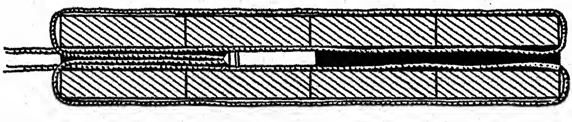


Fig. 63—The recommended method of making up a primer with pellet powder and an electric squib

Black Powder Primers with Other Electrical Firing Devices. Primer cartridges of blasting powder and pellet powder are made up with delay electric squibs, electric blasting caps, and delay electric blasting caps by the same methods as described for electric squibs.

Dynamite Primers with Blasting Caps and Safety Fuse. Preliminary operations include cutting the fuse and crimping on the caps. Before uncoiling fuse it is always a wise precaution to be sure that it is warm and flexible. A temperature of at least 65° F. is desirable. Where fuse has been exposed to the air for a considerable time the ends may be damp so that at least 1 in. should be cut off and discarded. In measuring lengths, the fuse should not be wound around a nail or peg, since these sharp bends are very likely to cause a fracture in the waterproofing coat. The cutting implement should have a clean, sharp blade to avoid smearing the waterproofing over the powder train with consequent trouble from misfires. Fuse should be cut squarely across and inserted in the cap immediately after cutting. Slanting cuts should be avoided because of the possibility of tapered ends folding over and blocking the end spit when inserted in the cap, and also because a slanting cut prevents properly seating fuse against the explosive compound in the cap. Shears of any sort are poor fuse

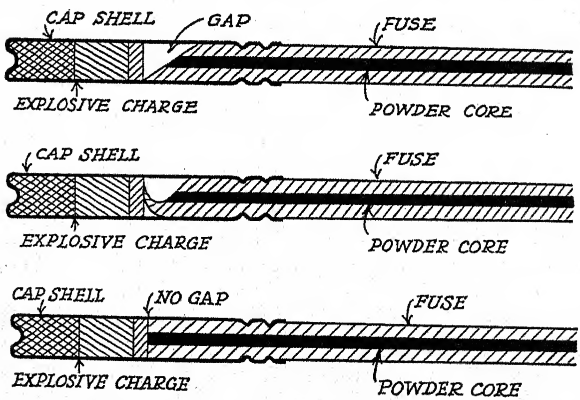


Fig. 64—Cutting safety fuse—(top and middle) poor cutting on a slant prevents seating, while a clean, square cut (bottom) allows proper insertion into blasting cap

cutters because they tend to squeeze the fuse flat in severing. Pocket knife blades usually give a beveled cut and are not recommended.

In small operations where safety fuse is used to a limited extent, the fuse cutting arrangement on the Du Pont No. 2

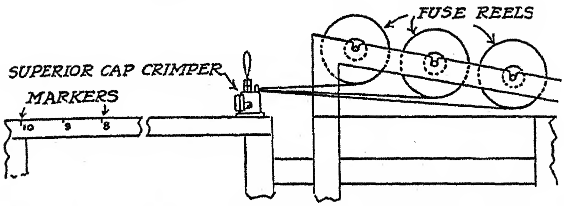


Fig. 65—Fuse cutting arrangement utilizing Du Pont Superior Crimper

Hand Cap Crimper is satisfactory, but where the consumption of fuse is considerable, some bench mounted method of cutting should be used. A typical arrangement with the Du Pont Superior Crimper permitting the cutting of as many as three lengths of fuse simultaneously is illustrated in Figure 65.

The reels are set up on a rack; the fuse from each is threaded through the eye in the crimper, pulled across the table to a definite marker, and cut off at the desired length by a single operation of the fuse cutter. This cutter is designed to use easily replaceable razor blades which insure clean, square ends on the fuse. Cutting and crimping can be performed at the same bench using the Du Pont Superior Crimper and the operation can be facilitated by a foot treadle arrangement shown in Figure 66.

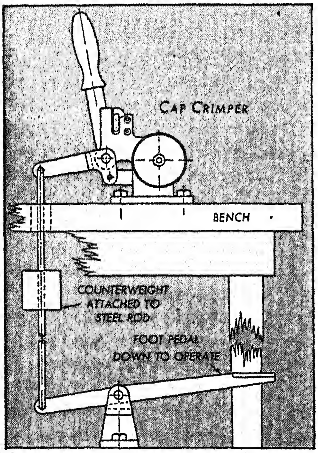
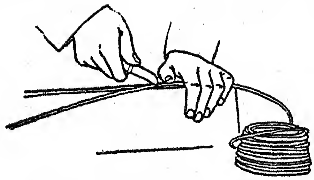
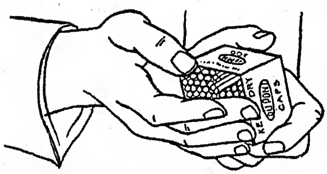


Fig. 66—Foot treadle arrangement for Du Pont Superior Crimper

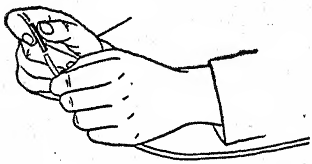
Fuse should not be handled roughly during or after cutting. Instances involving misfires have



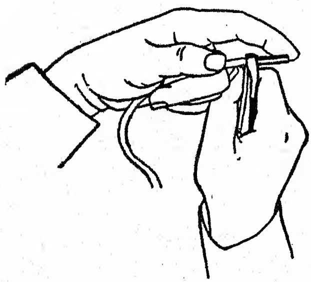
(a) Cut sufficient length of fuse.



(b) Take one cap from box



(c) Slip cap on end of fuse



(d) Crimp cap to fuse with cap crimper

Fig. 67—Crimping a blasting cap on a length of safety fuse

been investigated which show that the trouble was due to the loss of powder from the ends of the fuse before they were inserted in the cap. In some cases this was caused by slapping the ends of the fuse roughly upon the cutting bench or by shaking fuse after it had been cut.

The length of fuse cut should be sufficient to reach from the primer in the bore-hole to the collar plus some additional length outside the hole. In all blasting the minimum length should be sufficient to allow the blaster enough time to reach a place of safety after lighting the fuse plus what additional length is required for trimming. Under no circumstances should less than 2 ft of fuse be used.

Blasting caps should not be removed from their metal box until they are to be used. After removing the cover of the box, a single cap can be taken out by tipping the box and allowing the caps to slide gently into the hand as in Figure 67. If the whole box is to be used, all the caps can be emptied into a rubber covered tray which has no cracks and can be kept clean. A blasting cap should never be picked out of a box with a wire, knife blade, stick, or other hard tool.

It is a wise precaution to examine the interior of the cap to see that there is no foreign matter in it, such as grit, splinters, lint, and the like. If there is something in the cap, it should be shaken out gently. It is poor practice to blow into caps as this may introduce moisture. Damp caps, or any which may be suspected of having absorbed moisture, or caps which contain foreign matter of any kind, should not be used.

The fuse should be inserted gently into the cap until it seats on the explosive charge in the bottom of the shell. Fuse should never be twisted into place or seated with any force or violence. Emphasis is placed on the necessity of exercising care to see that the powder core in the end of the fuse is in actual contact with the explosive compound in the cap.

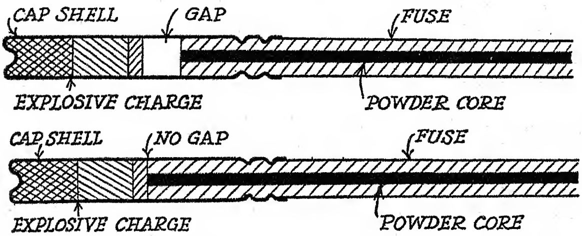


Fig. 68—(top) Fuse inserted in blasting cap improperly, showing gap, and (bottom) properly seated on explosive charge

Crimps should be tight enough to hold the cap securely in place. Loose crimps permit the fuse to pull away from the explosive charge in the caps or out of the caps entirely, causing misfires, burning charges, or delayed shots. Crimping can be accomplished successfully only by the use of cap crimpers which are instruments made especially for that purpose and which are essential for safety and efficiency. Crimps should be made near the open end of the shell. The Du Pont Superior Crimper, when properly adjusted and used, automatically places the crimp in the proper place.

When fuse is used in wet work, the crimp should be sealed to prevent water entering and dampening either the powder core of the fuse or the ignition compound of the cap. This can be most easily accomplished with the Du Pont Superior Crimper which gives a crimp that is as waterproof as the fuse itself, provided the jaws are properly adjusted. If this type of crimper is not available, Du Pont Cap Sealing Compound or other

recognized compounds containing no injurious solvents should be used. After the blasting cap is crimped to the fuse, the cap and two or three inches of the fuse above the crimp are dipped into the Du Pont Cap Sealing Compound for a second or two and hung up to dry. The caps should never be soaked in the compound. As soon as the dipped fuses have dried for about 30 minutes, the joint will have become watertight. It is recommended that waterproofed fuses be used soon after drying as the compound becomes brittle after a few days and may crack and admit water.

Compounds which are too liquid should not be used as they will run down into the cap through the vents and cause misfires. Compounds containing greases and oils, and paints which contain gasoline, benzene, carbontetrachloride, and similar solvents should not be used to waterproof the cap crimp as they also will penetrate the fuse and cause failures.

Underground capping stations should be dry and preferably heated so that caps, fuse, and capped fuse lengths will not absorb moisture.

Capped fuse lengths should not be made up for more than one day's requirements if it can be avoided, and if not immediately used, should be hung over a broad, curved surface or laid flat on a shelf. A number of misfires have been traced to the hanging of fuse lengths over small pegs or nails which cut into the waterproofing and materially weaken the water resistance of the fuse at this point.

It is recommended specifically in cold weather that fuse capped outside be stored in a warm place for at least a few hours immediately before being taken underground. This has cured a number of very serious complaints where fuse had been taken underground in a chilled condition and then used in wet holes.

Several methods of making up primers with dynamite and cap and fuse are shown in Figure 69; some are recommended as being satisfactory, while others shown are definitely wrong.

The safest primer is one in which the cap is inserted in the center of the cartridge essentially parallel to the long axis of the cartridge (A and B). The poorest primer is one in which the base of the cap is near the outside of the cartridge (C_1 and C_2) where it is likely to break through if tamped hard and cause a premature explosion through abrasion against the side of the hole. Primers A and B are designed so that there is

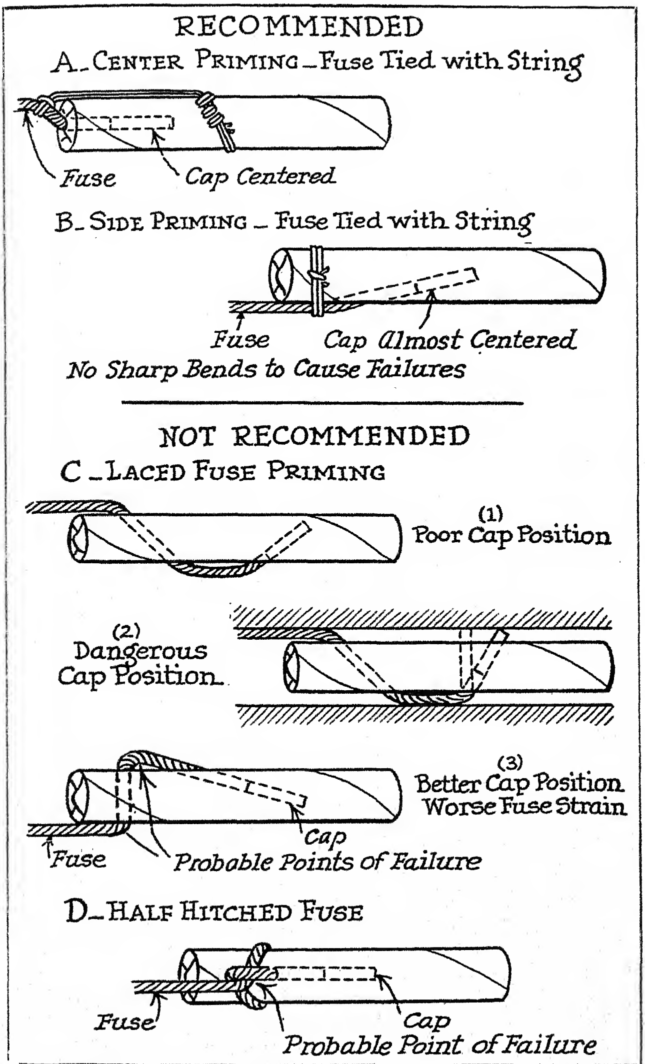


Fig. 69—Proper and improper methods of making up a dynamite primer with cap and fuse; (A) and (B) recommended methods; (C) and (D) wrong

practically no possibility of the cap being pulled out of the cartridge during the loading operations.

From the standpoint of effectiveness, the primer shown as A in Figure 69 is probably the best as it takes advantage of the fact that the greatest force of a blasting cap issues from the base in the direction of the longitudinal axis of the cap. Primer B is practically as good from the standpoint of effectiveness and has the advantage that the fuse is protected from injury by the end of the tamping stick. However, the fuse in A will not be injured if due care is used in the tamping operation. The methods shown in C_3 and D are very bad; while the fuse may not be injured by the tamping stick, the sharp bends caused by lacing may crack the waterproofing so badly that the least bit of moisture present in a borehole or in the stemming will cause a misfire.

Dynamite Primers with Electric Blasting Caps. There are numerous methods of priming dynamite cartridges with electric blasting caps but the preferred methods involve several fundamental principles:

(1) The detonator should be in the center of the section of the cartridge and parallel to the long axis of the cartridge.

(2) The wires should be attached so that they will not slip off or permit the cap to be pulled out of the cartridge; so that the primer can be loaded with either end foremost and drawn out of the hole, if necessary; and so that there are no sharp kinks, knots, or overlaps in the wires that might cause the wires to break or to cut into each other through the insulation and short circuit.

The best method of priming large diameter cartridges for well drill holes is shown in Figure 70. A hole is punched from the center of the end of the cartridge in a slanting direction so that it comes out the side of the cartridge four to six inches from the end. The cap wires are doubled over, threaded through this slanting hole, and finally looped around the cartridge. A second hole is punched in the end of the cartridge, a little off center and straight in. The cap is inserted in this hole. Finally all the slack is pulled out of the cap wires. This is a good primer because the cap is well placed, the wires do not overlap at any point, and the whole primer hangs vertically for easy loading in a vertical hole.

Primers may be made up with small diameter cartridges also by the method shown in Figure 70 but the smaller area of the ends does not easily accommodate both the wires and the cap. The cap, however, can be placed in the side of the

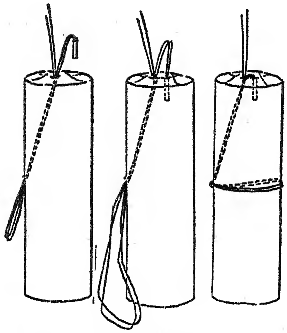


Fig. 70—The recommended method of making up a primer with a large diameter cartridge of dynamite and an electric blasting cap

cartridge, rather than in the end, if care is used to insert the caps deeply and at a shallow angle so that the base is centered and the axis of the cap is as nearly parallel as possible to the axis of the cartridge. The ideal variation of this method is shown as (A) in Figure 71 where the wires are passed laterally through the cartridge and the cap is in the end.

Another recommended method of making up a primer with a small diameter cartridge, however, is illustrated as (B) in Figure 71. Two holes are punched in the cartridge—one laterally through the diameter at the center and the other axially at one end. The cap is pushed all the way through the lateral hole, with about 10 in. of wire drawn through after it, then inserted in the end of the cartridge with the wires pulled back until they are tight. This method gives a primer that can be loaded with the cap pointed in either direction and eliminates all undesirable kinks and hitches. The primer can be recovered from the hole if necessary without putting any undue strain on the cap.

The most commonly used method of priming, (C) in Figure 71, places the cap in the same position as (B) but utilizes a half-hitch about the cartridge to anchor the wires. This primer has two faults: the primer can be loaded only with the base of the cap pointed out because the hitch tends to slip if the wires are pulled in the opposite direction; and the wires tend to cut into each other at the hitch creating the possibility of a short circuit.

Priming Dynamite with "Primacord." "Primacord" is a detonator throughout its entire length so that it primes every cartridge in a borehole in contact with it. Consequently it is not necessary to make up a primer cartridge when "Primacord" is used, but since it is usually desirable that the "Primacord" extend to the bottom of the hole, it should be attached to the first cartridge loaded into the hole. A good method of

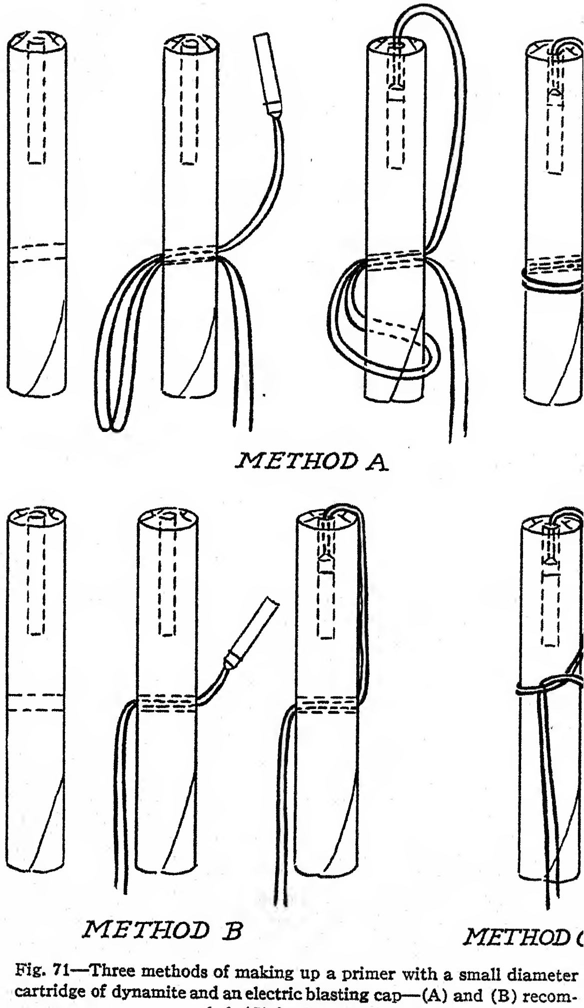


Fig. 71—Three methods of making up a primer with a small diameter cartridge of dynamite and an electric blasting cap—(A) and (B) recommended, (C) frequently practiced

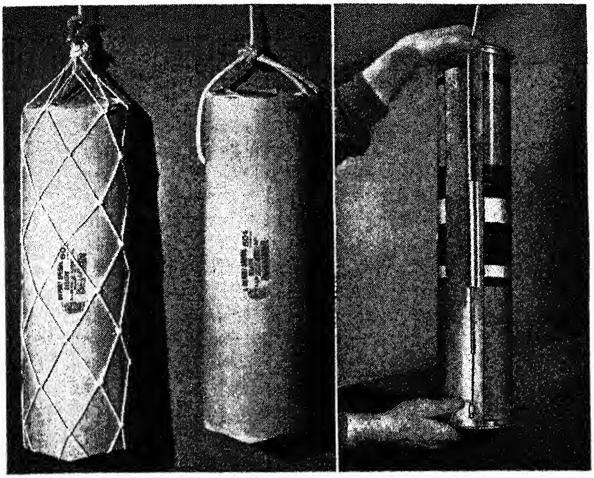


Fig. 72 — Recommended methods of attaching "Primacord" (left) to a lowering net on a cartridge of dynamite, (middle) by lacing through a cartridge of dynamite, and (right) by threading through the tunnel on a "Nitramon" primer

lacing "Primacord" through a cartridge is shown in Figure 72. A hole is punched through the diameter of the cartridge about 3 in. below the top. The end of the "Primacord" is threaded through the hole and tied securely as illustrated. When using cartridges which are supplied with lowering nets the "Primacord" is tied to the net or to the ring which is provided to facilitate lowering by line.

Priming "Nitramon" with "Primacord." One satisfactory method of attaching "Primacord" to a "Nitramon" primer is also shown in Figure 72. The "Primacord" is threaded through the tunnel on the side of the "Nitramon" can. A copper tube, similar in appearance to a blasting cap shell and provided with a cord attached, is crimped on the end of the "Primacord." The cord is then tied to the eyelet at the bottom of the primer can. A primer made up as directed can be loaded into the borehole at any position in the charge, but is frequently used at or near the bottom of the hole. Additional "Nitramon" primers can be threaded onto the "Primacord" line so as to be placed at any position in the borehole.

The cord supplied with the copper tube is purposely selected so that it will break from less tension than "Primacord." If there is excessive pull on the "Primacord" line for any reason the cord will therefore break, relieving the tension on the "Primacord." Obviously if there is too much pull on the "Primacord" line under these circumstances, or there is too much subsidence of the charge, the "Primacord" will be pulled out of the tunnel and the primer will fail to fire. When loading holes where customarily there is excessive subsidence, it is preferable, therefore, to lower the "Primacord" line into the hole with the cord attached to the bail of a can of "Nitramon," then load at least one more can of "Nitramon," and follow this with a primer threaded on the "Primacord" line. Under these circumstances there are at least 2 ft of "Primacord" line below the bottom of the tunnel on the primer can, allowing this distance for subsidence before the "Primacord" is pulled out of the tunnel.

HANDLING PRIMERS

Primers should not be prepared too far in advance of being used as some types of dynamite may commence to deteriorate from moisture absorption as soon as the cartridge is punctured. Powder also has a harmful effect on some initiators if they are left embedded in primers several days. If some storage is necessary, it should be dry and, in the case of fuse primers, warm.

If a large number of primers with cap and fuse are used, as in many mines, it may be best to have the fuse cut and crimped on the caps, and the joint waterproofed, if necessary, by one man at a central station. If delivery of the primers to the working face can be satisfactorily safeguarded, it may also be best to have the primers made at the central station where this operation can be more closely controlled. In general, however, it is probably safer to have primers made at the face just as needed for loading in the holes.

If the miner wears any open flame lamp, he should remove it while making primers and place it at a safe distance away in the direction toward which the air current is moving. At no time during the handling of explosives should a lamp be worn or carried in such a way that flame from it will come into contact with the explosives, or that the lamp may accidentally fall into them.

All primers should be handled with the realization that their potentialities for doing damage are much greater than those

of either the detonator or the cartridge of explosive alone. If the wires of electric primers are not short circuited, the greatest care should be taken to keep them from contact with charged rails, pipes, and machinery and from stray currents. The best insurance against premature explosion of electric primers is the use of short-circuited electric blasting caps. And it should be remembered that when short-circuited caps are used, the short circuit should not be broken until the very moment of connecting them in the blasting circuit.

PRIMING CHARGES IN BOREHOLES

The ideal method of priming charges of explosives in columns in boreholes involves two primary factors: the directional efficiency of the primer; and the directional efficiency of the whole charge of explosive.

In the case of black powder neither the primer nor the charge has any directional effect and other considerations govern the method of priming so that there is no one ideal method.

Dynamite primers, however, are more effective in the direction in which the base of the detonator is pointing. Hence, the primer should be the end cartridge of a column and the detonator should point toward the remainder of the charge. Furthermore, the charge tends to be least effective at the end where the detonation starts. Since the greatest amount of power is usually desired at the back of the hole, it is evident that the preferred position for the primer is at the outer end of the charge. This completes the ideal picture—the primer cartridge placed last in the hole with the cap pointing toward the back of the hole.

Where single shots are fired or where multiple shots are fired simultaneously, or in any firing where instantaneous electric blasting caps are used, the ideal method of priming dynamite charges can always be used. Where tamping is used in boreholes, however, it is recommended that the primer cartridge be placed next to last in the hole rather than last so that one unprimed cartridge is between the primer and the stemming to protect the primer from possible damage or rough usage during tamping.

In rotation shooting where all charges do not fire simultaneously, as with fuse, cap and fuse, or delay electric firing devices, the ideal method must give way to an important secondary consideration—the prevention of misfires. Where

two or more adjacent holes with primers near the collars do not fire together, the first that fires may cause the succeeding hole or holes to misfire in one of the following ways: (1) by compression accompanying concussion, if water is present, which can drive water into caps crimped on fuse; (2) by rarefaction, the opposite effect of concussion, which may tear the detonators out of the primers or the whole primer out of the holes; (3) by the rush of air and blasted material which may sever fuse before it has burned up to the point of severance; and (4) by blasting away the outer part of the adjacent burden cutting off a portion of the borehole, and carrying away with it the fuse, detonator, or whole primer from the delayed charge. All of these causes of misfires can be avoided by placing the primer at or near the back of the borehole. Usually the primer is the second cartridge placed in the borehole, one unprimed cartridge in the back serving to cushion the primer from rough contact with the back of the hole; and the detonator is pointed outward into the main charge.

Priming Black Powder Charges. In a borehole charged with black blasting or pellet powder, safety fuse should be in contact only with the primer. The time between lighting the fuse and the exploding of the charge is usually determined by the length of the fuse. If the fuse were in contact with any part of the charge in burning up to the primer, and if it were damaged so that it could fire from the side into the charge ahead of the primer, the effective length of the fuse would be decreased and the charge would explode sooner than full length of the fuse would allow. It is conceivable under these circumstances that the blast might explode prematurely and endanger men. In rotation firing, the result would be a hole exploding out of turn and a partial failure of the round. For this reason black blasting or pellet powder primers with safety fuse should always be placed in the outer end of the hole.

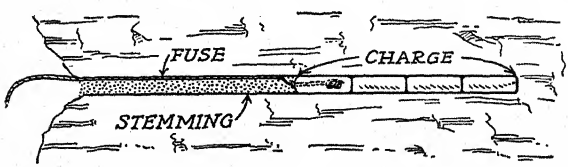


Fig. 73—The recommended method of priming black powder charges fired with safety fuse

In multiple shots or rotation rounds there is little likelihood of misfires from damping out, damage to the fuse or primer, or cut off holes as in the case of dynamite blasts. Black powder is not so violent in action as dynamite and is usually well tamped and protected by stemming.

When black powder charges are fired with electric squibs, delay electric squibs, or any other electric firing device, there is no possibility of premature firing as there is with fuse. Only the primer can explode first regardless of its position in the charge; hence, it can be placed anywhere desired. The usual method of priming is shown in Figure 74 with the primer cartridge in the middle of the charge.

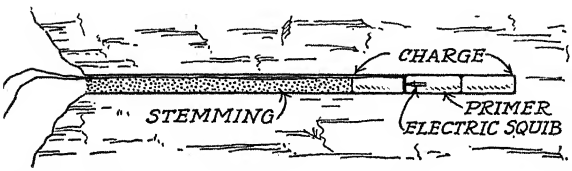


Fig. 74—The recommended method of priming black powder charges fired with an electric squib

Large charges of black blasting powder in well drill holes, sprung holes, and coyote blasts are usually fired with a dynamite primer. In sprung holes the dynamite primer should weigh between 5 and 10% as much as the black powder charge, while 5% of the charge is ample in coyote holes. The dynamite primers are usually placed near the middle or center of such charges so that the explosion can spread in all directions simultaneously.

Priming Dynamite Charges. Dynamite primers made up with cap and safety fuse may be placed in boreholes by one of the three recommended methods shown in Figure 75. In single shots the ideal method of priming (A) can be used, with the primer near the outer end of the hole and the detonator pointing toward the back. In multiple shots or rotation firing methods (B) and (C) with the primers near the back of the hole are recommended to avoid misfires from cut-offs or other causes as mentioned previously. Method (B) is preferred for dry work because the cap is pointing outward into the main charge. This requires bending the fuse sharply around the end of the primer which may break the coverings but result in

no harm if the hole is dry. If the hole is wet, however, sharp bends and possible damage to the fuse which might allow water to penetrate and cause a misfire should be avoided. Method (C) eliminates this objection—the cap points away from the main charge but this is certainly preferable to bending the fuse.

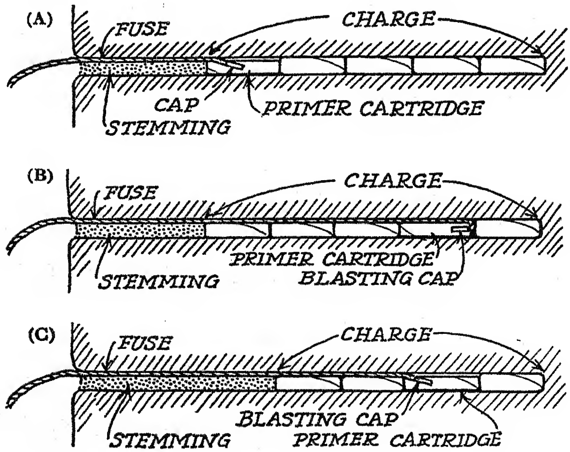


Fig. 75—Recommended methods of priming dynamite charges fired with caps and safety fuse: (A) for single shots, (B) for multiple shots or rotation firing in dry holes, (C) for multiple shots or rotation firing in wet holes

When electric blasting caps are used the ideal method of priming charges (Figure 76) with the primer near the outer end of the charge and the cap pointing toward the back, can nearly always be used. This applies equally to single shots and multiple and rotation firing. There is no danger from cut-offs in the latter instances because the electric blasting caps fire together and always are the first to fire in rotation rounds.

In long holes loaded with long columns of dynamite it is sometimes desirable to place the primer near the middle of the charge or more rarely to use two primers, one at each end of the column. These methods of priming have corrected trouble encountered at times where unexploded powder was left in the back of the hole when the primer was at the outer

end of the charge. "Primacord" has also been employed to overcome this trouble.

In well drill holes fired electrically the dynamite primer may be at the bottom of the hole, in the middle of the load, or on top, whichever appears to be the most effective. More than one primer also may be in the hole. Continuous loads may be

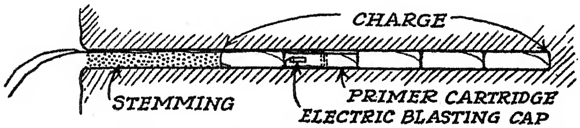


Fig. 76—The recommended method of priming dynamite charges when electric blasting caps are used

shot with two primers—top and bottom, or three—top, middle, and bottom; and decked loads must have a primer in each unit. These methods of priming are unnecessary, however, for the many well drill holes fired in multiple shots with "Primacord."

Primers in sprung holes are usually placed near the center of the portion of the charge in the sprung cavity.

In coyote tunnel shots the dynamite charge is loaded in units, one or more in each wing of the tunnel. One primer is required for each unit but usually two are used to provide added assurance of firing. Both are placed near the center of the unit charge so that the primers are entirely surrounded by the charge and the explosion can propagate radially in all directions.

Delay electric blasting caps are used for rotation firing in which work there is always the possibility of misfires from cut-offs. Consequently, the recommended method of priming when delays are used provides for placing the primer near the back of the hole with the detonator pointing outward, as in Figure 77.

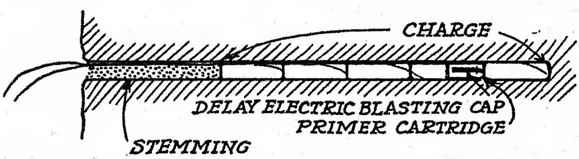


Fig. 77—The recommended method of priming dynamite charges for rotation firing with delay electric blasting caps

Priming Permissible Charges. One exception to the recommendations for priming dynamites applies to permissibles. Permissibles are, generally speaking, the least sensitive of the dynamites used in cartridges of small diameter. They will propagate and charges will explode completely if they are properly loaded with no gaps, or solid material between cartridges. Due to the conditions under which permissibles are loaded, however, special procedures must be used in priming and loading to insure the continuity of the charge. Boreholes in coal are always dirty—the drills leave considerable fine cuttings and dust which miners seldom scrape out cleanly. Furthermore, many boreholes are drilled with drill bits and augers of worn-down gauge so that they are rough and too small in diameter to permit easy loading. If cartridges were loaded one at a time it is almost certain that drillings would be pushed ahead of each cartridge and form an inert plug between succeeding cartridges. In rough, tight holes it is very easy for a cartridge to jam when it is being pushed back so that it does not make contact with the cartridge ahead of it. To prevent such separations of the charge it is strongly recommended that the

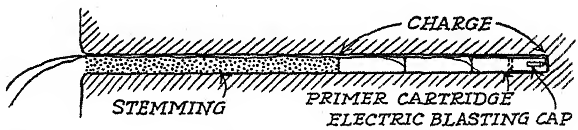


Fig. 78—The recommended method of priming charges of permissible dynamite

entire charge be placed in the collar of the borehole and all cartridges including the primer be pushed back together. Again, rough, tight holes may cause the charge to hang up before it is pushed to the back of the hole. Better control of the charge under such circumstances, even to withdrawing the entire charge if trouble develops during loading, is possible if the primer is the first cartridge of the column placed in the hole. Consequently, the preferred method of loading permissibles (Figure 78) provides for the primer being in the back of the hole with the detonator pointing outward.

CHAPTER IX

LOADING AND TAMPING EXPLOSIVES

Loading is the placing of a charge of explosive in a borehole. The technique of loading and the tools required depend upon the type of explosive and primer being used and upon the type of borehole being loaded. Explosives are loaded in cartridges in a variety of sizes or as loose, free running powders. They are loaded into boreholes of varying diameters, depths, and inclinations from horizontal to vertically downward or vertically upward. One factor in loading is the method of priming which should be chosen to meet conditions, as described in Chapter VIII. Another factor involves the control of the density of the charge—whether it is to be compact and concentrated or distributed by one of several methods.

After a borehole is loaded with the explosive charge, it is ordinarily plugged with stemming, some non-combustible material which serves to protect the explosive and to confine the power developed when the charge explodes. Tamping is the act of placing and compacting stemming over the charge.

SMALL DIAMETER BOREHOLES

Loading and Tamping Tools. For loading and tamping, only wooden tamping tools with no exposed metal should be used. Brass, copper or aluminum are not much, if any, safer than iron for use with high explosives. For shallow work in small diameter holes, an old broom or shovel handle is satisfactory. For deep holes when a long stick is needed, a straight sapling can be used to good advantage. In all cases the end of the stick should be cut square across.

Fig. 79—A wooden tamping stick—no metal parts should be used

For tamping horizontal holes, especially in the face of a quarry several feet above the floor, a heavy tamping stick, such as oak or hickory would be very difficult to manipulate and for this purpose a lighter wood, such as white pine or

bamboo, is very desirable. Bamboo fishing poles are light, straight, and strong, and if the holes are not too deep make ideal tamping sticks. It is distinctly dangerous for a powerful man to ram a charge of high explosives in a borehole with a heavy tamping stick.

For loading and tamping very deep holes, sectional poles of hard wood fitted at the ends with mechanical coupling devices are used. All such couplings are designed so that the sections can be disjointed only outside of the hole.

The recent increase in "long hole" shooting in ore mines has resulted in the development of several other ingenious types of loading and tamping implements. Perhaps the simplest consists of stiff, rubber hose, such as air hose, plugged at the tamping end. Holes may be drilled at intervals in the side of the hose so that water can be fed through it to lubricate the borehole.

Air hose has also been used to join five or six-ft lengths of wooden stick. The sticks are of the same diameter as the hose and are turned down at the ends to fit inside the hose. The fit must be airtight so that the sections can be pulled apart only by an effort greater than the drag of pulling a long length out of the borehole.

There are also several types of flexible permanent assembly. One consists of four- to six-foot sections of stick joined together with three-inch lengths of rubber-covered wire cable. Another very good arrangement comprises a chain of wooden sticks, two or three feet long, bored longitudinally and strung with a loose sliding fit on a strong smooth rope. The rope is embedded and anchored in the first stick which is the tamping end. When the first cartridges are loaded, a sufficient number of sections of the tamping device are fed into the hole to push the charge to the back. By drawing up the slack in the rope, the sections can be pulled into a stiff alignment to form a smooth, fairly rigid pole over the length used. As the pole is withdrawn some rope is allowed to feed back and the sections are permitted to fall to the bottom in a loose coil. As the hole fills up, fewer sections are required and enough extra rope is used to leave the unused sections on the bottom and out of the way.

Loading Charges. Loose granular powders, such as black blasting powder and bag-packed "Red Cross" Blasting Free Running Dynamite, are loaded into a dry, vertical down hole simply by pouring them out of their kegs or bags into the hole. If the required charge tends to rise too high in the hole, load-

ing may be interrupted when necessary to pack down the charge with a tamping stick. When the charging is completed, all powder spilled around the mouth of the hole should be brushed into it.

Boreholes should never be charged with blasting powder or other explosives when a steam shovel, locomotive or any other source of sparks or hot coals is operating in the vicinity, without complete protection in the way of screens and covers over the powder. Sparks and hot cinders are thrown considerable distances from the smokestacks of these and other boilers, and numerous fatal accidents have been due to them. It is much safer not to charge the boreholes at all during the time steam shovels and locomotives are operating in the vicinity.

If granular powders are to be used in holes that are slightly wet, or in holes other than down holes, they must be cartridged. "Red Cross" Blasting F. R. Dynamite can be obtained in cartridged form for such purposes but the bag-packed powder as well as black blasting powder can be cartridged in tamping bags which provide a good pre-formed cartridge. Cartridges can also be prepared from paper, preferably blasting paper, which is tough and moisture-resistant, by wrapping it tightly around a smooth, cylindrical wooden stick, a little smaller in diameter than the borehole, and crimping one end over the end of the stick to form a closure. The paper shell is slid off the stick and filled with powder, well shaken down, to within an inch or two of the top. The open end is then closed by crimping the excess paper. When holes are wet the cartridges, as well as the primers, should be heavily coated to exclude water, particularly the folds and crimps. Soft soap or wax are good water repellants but grease should not be used. Rather than prepare cartridges for black blasting powder, it is usually preferable to use pellet powder.

Pellet powder should be loaded in the cartridges as they are received. Pellets should not be removed from the wrappers. Some blasters tear off the ends of the cartridges but this is unnecessary and to be avoided when holes are wet.

There are a number of methods of loading charges of cartridged powders. Cartridged black blasting powder, pellet powder, free running dynamite cartridged in small diameter, and permissible dynamite, all of which require close contact between successive cartridges to insure propagation, should be loaded by placing all the cartridges in the charge, including the primer, in the collar of the borehole and pushing them all

back together. When cartridges are loaded in this manner the charge is continuous but not compacted. With these powders, however, the latter is not necessary and sometimes, as in the case of permissibles, not desirable.

Dynamites, other than the exceptions noted above are loaded into holes under conditions and practices dictated generally by the charge density desired in the borehole.

Controlling Charge Density. The du Pont Company manufactures dynamite in a wide variety of strengths, densities, and sizes so that density control is possible largely through the proper choice of grade and size. In many instances, however, it is desirable from the standpoint of economy and results to supplement this form of control by mechanical methods of further compacting or distributing charges.

In tight work and hard ground, conditions normally encountered in development work in ore mines and in tunnel construction, for example, it is desirable to have essentially all of the explosive energy needed in the borehole concentrated at the back. In some other kinds of blasting, it is possible to get this effect by springing the boreholes, but this is not usually feasible under ground. In fact, boreholes are generally smaller at the back than at the front which is an added handicap. The best that can be done in this case is to load explosives of high density and weight strength and to load the charges so as to obtain the maximum possible density in the borehole. This latter can be accomplished by: slitting the dynamite cartridges (except primers) so that the shell ruptures and the powder expands snugly into the hole when pressure is applied; by loading them one at a time; and by pressing each cartridge firmly into place.

The proper method of slitting dynamite cartridges is simple, but nevertheless this is often very poorly done. In slitting cartridges, two longitudinal cuts should be made, one on each side of the cartridge as nearly opposite as possible. The cuts should extend entirely through the layers of paper. They should be about four inches long in an ordinary eight-inch cartridge. Longer slits, especially if they cut through the ends of the cartridge, are undesirable as they may cause the shell to unravel and spill out the powder during loading. Shorter slits are less effective as they will not permit the cartridge to collapse fully. Slitting should not be done until just prior to and at the place of loading. This prevents deterioration by

moisture penetration, to which some dynamites are susceptible, and minimizes spillage of powder caused by handling after cartridges are slit.

When several cartridges are placed in a borehole and they are then all pressed into place at one time, the top cartridge mashes up in the proper manner but those below simply buckle in the middle, leaving considerable air space around them. To make the most effective load each cartridge should be loaded and pressed into place singly.

An improper practice that is fairly general consists in wielding the tamping stick too vigorously when loading explosives, especially gelatins. The end of a tamping stick wears down in a short time to an appreciably smaller diameter. When such a worn-down tamping stick is driven with great force, it penetrates the end of the cartridge and punches a hole in the powder that succeeding cartridges do not fill. Thus pockets, varying in size with the force of the tamping, are left in the

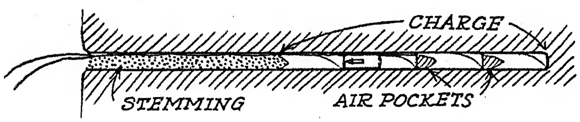


Fig. 80—Air pockets in charge made by too vigorous tamping with a worn-down tamping stick

charge and the density of the load is lowered accordingly. Tamping sticks should be kept cut square across and replaced when worn down in diameter. No violent effort is required to compress dynamites solidly in the borehole, especially gelatins which are soft and plastic. Two or three short, firm, pressing strokes, rather than sharp, hard, pounding blows, will pack the charge most effectively.

Under other conditions of blasting a low loading density is found to be of advantage, and spacers either of wood, lean concrete, or pottery are used to distribute the explosive charge. In many underground mining operations in Canada, it is now quite general practice to use spacers for one or more of several purposes: to prevent the leaving of collars in stope blasts; to square up the corner holes in development rounds; and to improve fragmentation in shrinkage stoping operations where long holes are employed and where the boreholes, by reason

of the width of the stope, are quite easily broken. In each of these cases a small charge per unit length of borehole is sufficient for the work.

Spacers 8 to 10 inches in length are usually employed; longer ones are not recommended, but some up to 18 inches have been used. Their cross section should be about one-half the diameter of the borehole. Either round or square spacers can be used, but the latter are preferable since they cannot fill the hole completely.

Wooden spacers are usually most readily procurable, but their use is open to the objection that increased quantities of toxic fumes are produced. They should therefore be employed only in well-ventilated places. Spacers of clay, molded to shape and fired in a furnace, have been used to overcome the problem of increased fume production. Some of these are shaped in the form of hollow, round, or square tile. These have the advantage of filling a smaller proportion of the cross section of the borehole and thus are less likely to interfere with propagation of the charge.

If a charge is primed near the bottom of the hole, at least two cartridges, including the primer, should be loaded in the bottom of the borehole before any spacers. A spacer should never be placed between a cartridge in the bottom of a hole

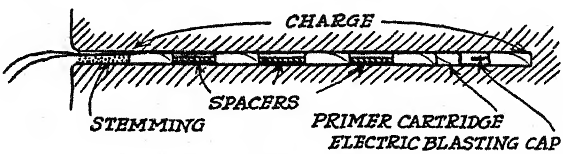


Fig. 81—A loaded borehole showing the use of spacers

and the primer. After loading of the charge has been properly started, a spacer and a cartridge or a spacer and two cartridges can be loaded alternately until the charge has reached the desired point in the hole.

Tamping. Tamping with a good stemming material serves many purposes, all of which contribute generally to the safety and efficiency of blasting.

One of the principal functions of stemming is to protect loaded charges from accidental ignition. This is particularly important where black powder is being used, especially when

it is fired with safety fuse and when miners are wearing open flame lamps. Dynamite is less easily ignited but under the same circumstances stemming contributes materially to safer working. Charges in holes pointed downward should be covered by stemming since it is so easy for sparks from a number of sources to drop into them.

In rotation firing, stemming serves to protect the charges which are delayed from the effects of the explosion of the preceding holes. In tight headings, such as drifts, tunnels, and particularly raises, and also in stopes where holes are inclined upward, charges may be partially unloaded by concussion and jar from the explosion of cut- or lead-off holes. Similarly, in sinks, and in stopes where holes are inclined downward, the blast from the first holes to fire may drive water into the powder and primers of the delayed charges causing them to misfire. Stemming tends to shield charges from both of these effects.

The most familiar function of stemming is that of confinement. The resistance in the collar of a borehole offered by good stemming exerts a retaining and diverting effect on the energy developed during explosion. Loss of energy through the mouth of the borehole is lessened and the forces of the explosion are directed more effectively into the surrounding material. Black powder must be stemmed because it develops pressure so slowly that there is a great tendency for it to blow out through the borehole. Stemming also may increase the efficiency of dynamites an appreciable extent depending upon the type of blasting.

Finally, non-combustible stemming decreases the amount of poisonous gases produced by a blast at least to an extent corresponding to the reduction in the total explosive charge permitted by the extra confinement.

The use of stemming in some blasting, such as coal mining is compulsory for the sake of safety. In most work aboveground, holes are usually stemmed without question. Where the use of stemming is not absolutely necessary and involves some added expense and effort, as in underground ore mining and in tunnel driving, however, the practicability is frequently questioned. The majority opinion, nevertheless, is that stemming in a borehole has advantages which warrant its use under such conditions.

The best stemming materials for small holes where the "plug" effect is required are, in the order of their effective-

ness: (1) a mixture of sand and plastic clay (about 2 to 1 proportions), (2) clay, (3) sand, and (4) loam. All of these should be used in a damp state; dry materials may be used, but they are not so cohesive and therefore not so effective. Light, dry, non-combustible materials, such as rock dust often used in coal mines, are good from the safety standpoint, but not especially efficient as regards confinement. In coal mines "bug dust" (cuttings from drills or cutting machines) or any form of combustible stemming should never be used. Paper wads, rags, straw, sawdust, and similar inflammable materials are likely to catch fire and should not be used for stemming if flaming debris involves any hazard.

Stemming material for small holes should be free from coarse pieces of stone or grit. Where safety fuse is used, coarse, sharp tamping may cause damage to the fuse and lead to misfires or burning charges. In electrical firing there is danger of damaging the insulation on the wires, thus causing misfires due to short circuits, or even of cutting the wires themselves. The stemming should be packed in tamping bags to make dummy cartridges because in this form it is more easily placed in the borehole, particularly in holes pointed upward, and the danger of cutting or abrading the cap wires or fuse is reduced to a minimum. Tamping bags are time savers as they can be easily and quickly filled outside the mine and sent in with the dynamite at loading time, thus decreasing the time consumed in loading the boreholes and encouraging miners to comply with rules requiring the use of stemming.

After choosing the proper stemming material and tamping tool, care should be observed during tamping not to damage safety fuse or the leg wires of electrical firing devices.

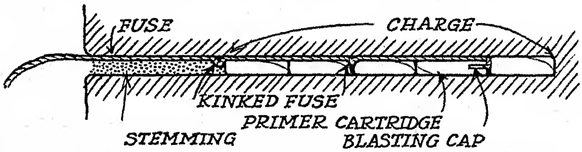


Fig. 82—Fuse kinked due to careless loading and tamping

The chief precaution to be used in tamping with fuse is to hold the fuse taut at one side or the top of the hole so as to avoid kinks, abrasion of the fuse covering from the tamping stick, or other damage which might cause a misfire from

moisture present or the ignition of the charge from side sparks. Leg wires also should be held taut and to one side of the hole to avoid abrading the insulation or cutting or breaking the wires.

The first few inches of stemming should be pressed only lightly to avoid injuring the primer if it is in the outer end of the charge. The rest of the stemming should be packed in firmly, using the wooden tamping stick in one hand and holding the fuse or leg wires taut and out of the way with the other hand.

LARGE BLAST HOLES

Loading and Tamping Tools. A tamping block on the end of a rope is used for tamping explosives and stemming in deep well drill holes. This block should be of hard wood to resist wear. It may be weighted so that it will sink in water. It should not have any exposed metal parts and should not be too heavy for normal everyday use. It is operated by lowering into the hole until it rests on the powder or stemming material, then raising it a foot or two and letting it drop.

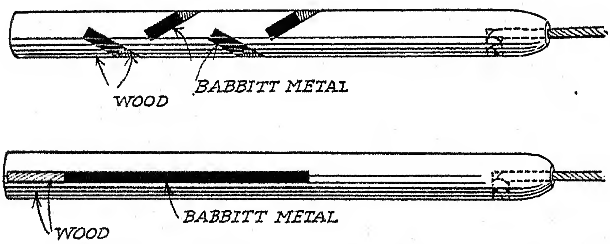


Fig. 83—A tamping block for deep holes. The hole for the rope is bored from the center of the end and the rope knot countersunk into the side. For use under water a hole or holes are bored and filled with babbitt or lead and then a wooden plug is driven in to close the holes

This tamping block should not be used for forcing dynamite down a hole or for attempting to free a cartridge which has become stuck during loading. A tamping block of the type shown in Figure 84 should be used for this purpose. By churning this spike or wedge very carefully up and down a few

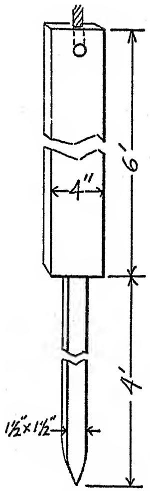


Fig. 84—Tamping block used to dislodge stuck cartridges

times, the stuck cartridge can usually be broken up so that it may be dislodged by the shoulder of the block.

Horizontally inclined sprung holes and gopher holes are usually loaded by means of a long slender pole frequently made of bamboo similar to a tamping stick except that one end has a slim sharp point.

A similar long tamping stick is necessary when loading vertical sprung holes with black powder or free running dynamite in order to insure complete filling of the pocket.

Sprung Holes. A sprung hole should be carefully examined before loading to see that it is open and especially to make sure that it has cooled off from the heat of the springing shot. If this latter precaution is neglected, hot rock in contact with the charge may cause a premature explosion.

Vertical sprung holes are loaded most easily with granular powders which can be poured conveniently. Some tamping with a long light tamping stick is necessary, however, in order to insure filling the chamber completely. "Red Cross" Blasting Free Running grades are recommended for this type of work. Black powder has been used extensively in sprung holes, but has been largely supplanted by the "Red Cross" Blasting Free Running grades which eliminate the spark hazard. Sprung holes should be tamped all the way to the collar with stemming as described under small diameter boreholes.

When cartridged dynamite is used, it may be loaded whole or cut up into halves or quarters, dropped into the hole and pressed into a compact charge. Gelatin dynamite should be used if the holes are wet. Under such conditions, gelatins are often shucked and cut up into small sections to facilitate compact loading.

Horizontal sprung holes are usually loaded by sticking each cartridge of dynamite firmly onto the point of a long light loading pole. The cartridge is pushed carefully to the bottom or the back of the hole and shaken off. Special care should be taken in sprung holes to insure compact loading and eliminate air spaces. The primer cartridge should be placed in the pocket

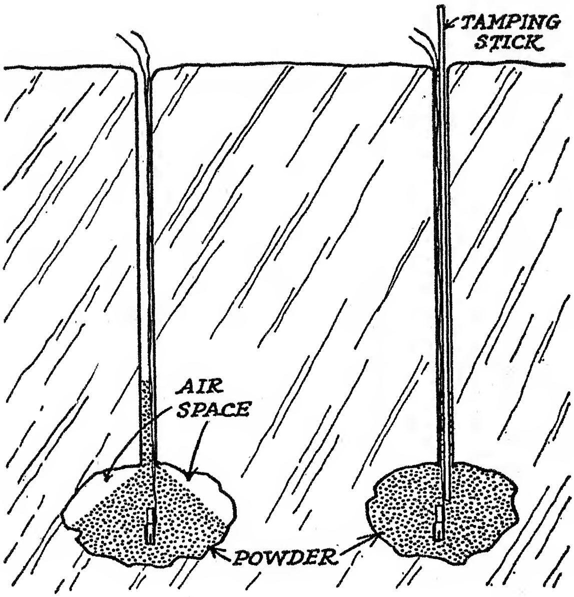


Fig. 85—Vertical sprung hole showing (left) chamber not entirely filled with powder and (right) chamber completely filled when powder is properly tamped

of the sprung hole so that it will be completely surrounded by the charge. The primer should consist of a 40% or stronger dynamite and should have a weight equal to about 5% of the charge.

Well Drill Holes. Before they are loaded, well drill holes should be tested with the tamping block or visually examined, using a flashlight or a reflected beam from a mirror for illumination to make sure that they are unobstructed and otherwise in condition for loading. Obstructing rocks or scale from caving holes should be broken loose and pushed to the bottom with the tamping block. Water should be bailed out if the ground is not so wet that the holes will fill again too quickly.

Dynamites are loaded in well drill holes either by dropping or by lowering with a rope. Cartridges may be dropped into

shallow holes, or in smooth deep holes in which the cartridges fit tightly enough for air pressure beneath them to retard their fall. In holes that are rough, or where the cartridge might fall too fast, the charge should be let down with a lowering rope. Large diameter cartridges can be obtained enclosed in lowering nets which are a great convenience in loading. Usually a hook is tied to the end of the lowering rope. The hook can be slipped under two or three strands of the netting which will support the cartridge during lowering but which can be broken by a jerk when the cartridge is down, thereby freeing the hook and rope. When the cartridges are not in lowering nets they can be suspended and lowered on a wooden skewer attached to the lowering rope and thrust into the cartridge deeply enough to support its weight. When the cartridge is down the skewer can be pulled out by a jerk on the rope.

In most holes it is unnecessary to tamp the charge to get a high loading density. Either the cartridges fall with enough force to expand themselves and compress those beneath or the weight of the column is enough to compact the charge fully. When holes contain water and under certain other conditions, it may be necessary to compress the charge with the tamping block. Cartridges of gelatin dynamite (and of ammonia dynamites, loaded in dry holes) should be slit, if compact loading is desired.

In well drill holes that are ragged or partially caved, it may be impossible to load cartridged dynamite. If this condition is normal for certain ground, the kind of powder used should be such that it can be loaded loose. In dry holes the "Red Cross" Blasting Free Running grades which can be poured down the holes would be ideal. In wet holes, however, it would be necessary to use a gelatin dynamite, remove the gelatin from the cartridge, cut it up into pieces that will go down the hole and load these. If difficulty in loading cartridged dynamite is unexpectedly encountered so that loading must be completed with loose powder, "Red Cross" Blasting Free Running should be used if it is available. Otherwise, loading may be finished with shucked dynamite, preferably unwrapped gelatin cut up in pieces.

However, if only ammonia dynamite is on the job the best that can be done is first to clean the hole as much as possible by vigorous use of the tamping block and then pour the powder, a little at a time, in a thin stream down the center of the hole, watching all the time to see whether it is going to the bottom of the hole. If the powder blocks the hole and builds up at

some point above the level to which the quantity loaded ought to come, do not attempt to force it down with a heavy tamping block. Good results can usually be obtained by using a light, thin pole or a special tamping block similar to that shown in Figure 84. By this means a hole should be punched through the center of the powder to start it running downward again. In tamping a loose charge to compact it, the tamping block should be raised and lowered slowly. When it is taken out of the hole, place the end in a clean empty box or lay the block on a mat of gunnysacks to prevent grit or bits of rock from sticking to it.

The practice of shucking ammonia dynamites for pouring into holes is allowable in emergencies but should never be regular practice. These dynamites are not suited for this purpose and are less safe as well as less convenient to use under such conditions than the "Red Cross" Blasting Free Running grades which are particularly designed for loading in the loose state.

Charges in well drill holes may be loaded in a continuous unbroken column or they may be broken or decked. Deck loading is employed when the charge required to blast the whole burden on a particular hole does not rise high enough in the hole to break the top properly; or when the hole passes through a slip, fault, or intrusion of some soft material and the explosive is not needed or desired in that portion of the hole. In deck loading a charge for better distribution, the column load in the bottom is built up until there is enough explosive to break the bottom with certainty. Then the remainder of the charge consisting of one or more separate units of the most effective size are spaced in the hole where they will give the best performance. The units or decks are spaced and separated by stemming material.

Well drill holes are fired either with electric blasting caps or "Primacord." "Primacord" is particularly adapted to this method of blasting since it is so convenient to handle and is generally safer. It is particularly applicable to deep holes where a number are shot in one blast and to deck loaded holes. In shallow holes "Primacord" is sometimes hard to justify because of its expense in relation to the comparatively small quantities of powder per hole; but even under such circumstances some operators prefer to use it because of its safety features.

When charges are fired with "Primacord" a single strand is attached to the first cartridge lowered into the hole so that

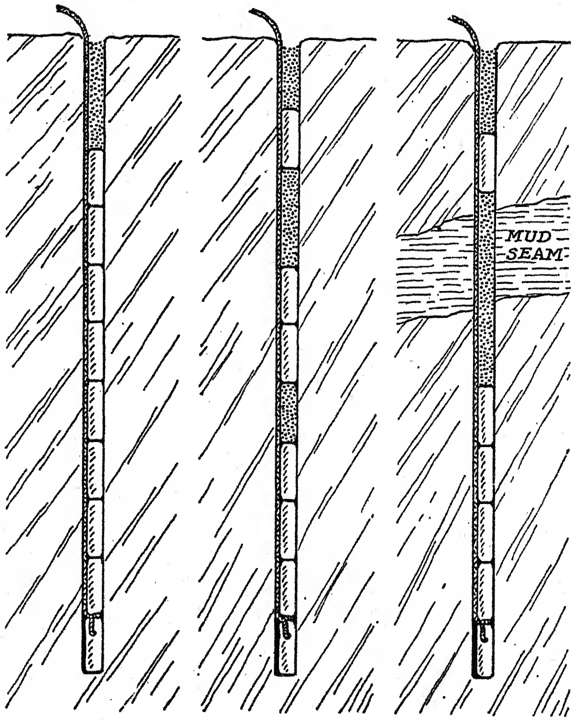


Fig. 86—Well drill holes showing (left) a column load, (middle) deck charges to distribute the explosive energy toward the top of the hole, and (right) a deck charge to break top rock above a mud seam

it extends to the bottom of the hole and primes the entire length of the charge or each unit of a charge when it is decked. When electric blasting caps are used in column loads two primers are loaded in each hole, usually at the top and bottom of the charge. In decked loads one primer is required for each unit. It is obvious, however, that if a decked load consists of numerous units, "Primacord" is much simpler to use.

If a thunderstorm comes up while holes are being loaded in an outside blasting operation, the loading should be stopped at once for there is danger that lightning may strike the ex-

plosive direct or may discharge electricity into detonator wires and thus set off one or more of the primed charges. All but one or two men should be sent off the work. Detonator wires in holes already loaded should be short circuited. Loaded holes should be covered and all unloaded explosives, detonators, and "Primacord" should be returned to the magazines. The time to ward off accident from a thunderstorm is when the first threat of storm is observed. If work is continued until the storm actually breaks, the steps recommended to protect the explosives from lightning become fraught with danger for the men carrying them out. Furthermore, an approaching storm frequently creates as much electrical disturbance as one in progress.

After loading, well drill holes should be completely filled with stemming material, preferably with sand or clean crusher screenings. Ordinarily it is not necessary to use a tamping block to settle the stemming as it will be sufficiently compacted by the action of shoveling it down the hole and by its own weight. Care must be observed both during the loading and during the tamping operations to avoid damaging either the "Primacord" or cap wires.

Gopher Holes. These are relatively large diameter holes, usually driven in a horizontal direction at the bottom of a face of rock. They are too small to permit the entrance of men and are loaded by affixing each cartridge securely on the sharpened end of a long, light pole. The cartridge is carefully pushed to the back of the hole and disengaged from the pole by a twist or jerk. It is very important that these holes be completely filled with stemming. The easiest way to do this is by the use of tamping bags 4 or 5 in. in diameter. These may be filled with fine ore screenings or sand and pushed to the back of the hole with a tamping block attached to a wooden pole.

Tunnel or Coyote Hole Blasts. In this method of blasting, explosive charges are usually loaded in compact units at the end of and at intervals along each wing. The explosives used are black blasting powder, bag-packed free running dynamite, or large size cartridges of other dynamite grades. Black powder is loaded by stacking the kegs on their sides in a compact pile. Loading in bulk in this manner is more convenient and much safer than opening the kegs and emptying the powder, which is wholly unnecessary. Dynamite, either bag-packed free running grades or large diameter types, may be loaded in the

original cases or may be removed and stacked in neat, compact units at the proper points.

As mentioned previously, the usual practice is to divide the charge into units spaced at intervals along each wing. This practice should always be followed in the case of black powder, but there have been several shots fired in trap rock, in which the explosive was strung out along the floor of the wings like a carpet extending from the extreme end of the wing up to within 12 or 15 ft of the main tunnel. Results with this type of loading were just as satisfactory in this particular quarry as when the charge was placed in units.

Coyote holes are, of course, large enough for men to enter so that the explosives can be carried in or wheeled in on a small truck or wheelbarrow. Sometimes the kegs or boxes are slid in on well-laid planking with the loading crew stationed at intervals passing the containers from man to man.

Great care is necessary in loading these large quantities of explosives especially if they are removed from the original cases. Electric flashlights with insulated cases and no live points are recommended for use inside the tunnel. Open lights should not be allowed and possibilities of sparks as from workmen's shoes must be reduced to a minimum. Tunnel blasts are fired with electric blasting caps or "Primacord" or in some cases with both. When electrical firing is used, the leading wire must be installed prior to loading. It should be strung through ring pins driven into the roof of the tunnel near one side where they are out of the way during loading. Branch lines into the wings should be connected to the main line with cleanly scraped, tightly wound and well-taped joints.

With electrical firing, there should be two dynamite primers in each unit. These primers may consist of single, large diameter cartridges of dynamite, a bundle of large cartridges

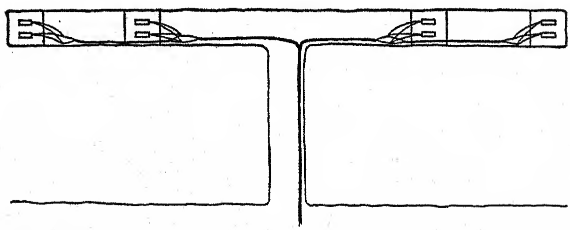


Fig. 87—Diagram of wiring for tunnel blast with power current

in which one is a primer, or a case of either large or small size cartridges in which one is a primer. If the dynamite is being loaded intact in the original cases, the primer cases should be carefully opened, one cartridge primed in the recommended manner with an electric blasting cap, a notch cut in the side of the box through which the wires will extend and the case carefully closed. This should, of course, be done outside the tunnel.

In the case of a black powder blast, the dynamite primer should be equal in weight to 1% or more of the black powder charge. In the case of "Red Cross" Blasting Free Running Dynamites, the primer should amount to about 5% of the total charge. In both cases the dynamite used for the primer should be 40% strength or greater.

The primers should be placed in the unit loads so that they are completely surrounded by the charge. It is usually necessary to connect up the electric blasting caps in the primers to the leading wires as each unit is loaded. It is obvious that under such circumstances the greatest care must be observed to protect the leading wires from stray currents or any contact with a source of power. Also, no loading should be done during the approach or occurrence of a thunderstorm.

All electric blasting caps should be tested with a circuit tester before inserting in primer cartridges. All connections should be tested at frequent intervals during loading and about every 10 ft during the tamping. This will insure a break in the circuit being discovered before a considerable amount of work is required to uncover it. The usual practice is to connect all electric blasting caps in a tunnel shot in parallel.

When "Primacord" is used, a loop should be run from the entrance of each wing along one side of the tunnel all the way to the back and then returning to the wing entrance along the other side. Both lengths of "Primacord" should be in intimate contact with the dynamite in each unit. When all of the charges have been placed and when the wings have been stemmed almost to the main tunnel, a main loop of "Primacord" should be strung from the entrance down one side of the main tunnel all the way to the back and then returned to the entrance along the other side. The two ends of "Primacord" issuing from each wing should be tied to the main loop by the standard connection. Naturally, the wings on the right-hand side of the adit will be tied to the right-hand loop and the ones on the left to the left-hand loop. As in the case of electric blasting, extreme care must be used to prevent injuring the

"Primacord" during the loading and tamping operations. Some operators lay the "Primacord" in a grooved board over which a cover-board is placed, thus completely protecting the "Primacord" except at the points where joints are made. The two ends of "Primacord" extending from the main tunnel can be joined and detonated in the usual manner.

If black powder is used, it is advisable to tamp tightly both between the units and from the last units out to the mouth of the tunnel. Ordinarily the muck taken out of the tunnel is used for stemming, but bags of sand or screenings are preferred by some. Bulkheads of heavy timbers notched into the side walls and the stemming packed behind them, or brick, or lean concrete bulkheads are sometimes used. Usually it is sufficient to pile the muck closely against the face of the charge, but partial bulkheads every 10 ft insure better packing of the stemming material at the top of the tunnel.

When the explosive is dynamite, the modern practice is to omit all stemming between the units and to tamp each cross cut only from the last explosive charge to the main tunnel after which, of course, the entire main tunnel must be tamped clear out to the face (Figure 88). Blasts solidly stemmed in

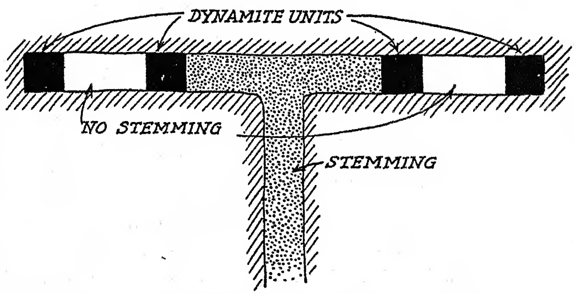


Fig. 88—Method of tamping tunnel blast loaded with high explosives

this way give just as good results as when the cross cuts between the units are also tamped and the saving in the former case in loading time and labor cost is considerable. It is recommended that the last charge in each cross cut be located at least 6 ft from the rib of the main tunnel so that at least 6 ft of solid stemming will be assured in the cross cut before stemming is started in the main adit.

CHAPTER X

FIRING BLASTS

The final act in blasting is the actual firing of the loaded charges. With each method of firing some preparation is required, such as trimming fuse, connecting up and testing electric circuits, connecting up "Primacord," and the like. This chapter covers both the preparations for firing and the firing of blasts.

Attention should be called here to a very important precaution in the firing of blasts—the safeguarding of all persons, including those working directly on the blast, those engaged in other work in the vicinity, spectators, and, in the case of outside work, passing traffic.

FIRING WITH SAFETY FUSE

It has previously been stated that safety fuse is used for firing single shots and for multiple shots in rotation, but not for firing two or more charges which must detonate simultaneously. Also, the requirements which dictate the minimum lengths of cut fuse to be used in making primers have been stated. For proper methods of firing with safety fuse the only further description necessary is that on trimming and lighting.

Trimming Safety Fuse for Rotation Firing. In dependent or rotation firing, it is necessary to adjust the lengths of fuse by cutting different amounts from the fuse ends protruding from the hole. They should be trimmed (varying the length cut off) so that the holes which are intended to fire first have the most trim or the longest length cut off. The amount to cut off depends upon the length of fuse being used. A good rule is to use a minimum trim of ½ in. per ft of fuse length—a larger trim if practicable. The fuses should be lighted in the order in which the holes are expected to fire.

In some instances premature shots have been caused by mistakenly trimming a fuse in some hole twice or more. This can be avoided by dipping the uncapped ends of the cut fuse lengths for an inch in a color dye or paint and allowing them

to dry. Thus, a fuse hanging from the hole without this color would serve to warn that it had already been trimmed.

Lighting Safety Fuse. In safety fuse, the powder core burns inside the wrapping which prevents seeing the fire. Some brands emit smoke through the wrapping as the powder burns; with others the only way of knowing that the fuse is lighted is by the end spit and the smoke issuing from the lighted end. The end spit is a jet of flame about 2 in. long that shoots out of the end of the fuse the moment the fuse is lighted. It lasts about a second and is followed by smoke which rises from the end of the fuse. No method of lighting should be used which obscures or conceals this evidence that the fuse has been lighted. Fuse should never be lighted by a gasoline or kerosene torch, a burning stick of wood, roll of paper, or a cigar or cigarette. At best these methods are slow and unsure. Blasters, delayed or confused in attempting to use such methods, have been fatally injured by shots that exploded in their presence. The preferred and commonly used methods of lighting fuse eliminate these hazards and they only should be used.

Safety fuse may be lighted properly in numerous ways but regardless of the method used the end to be lighted should be

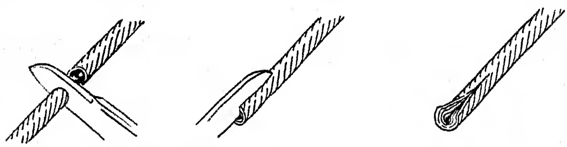


Fig. 89—Preparing safety fuse for lighting

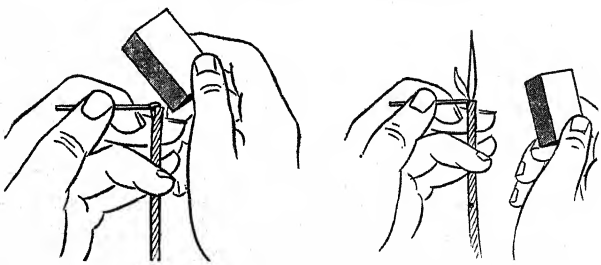


Fig. 90—Lighting safety fuse by holding match-head in powder core and striking

freshly cut and clean. Some methods of lighting require that the end be slit for about a half inch so as to expose more of the powder train, but this should be done in such a manner that the powder does not spill out. Single fuses properly cut and slit may be lighted with an ordinary match but only the initial flare is hot enough to give sure ignition. One method of lighting with matches is to hold the match-head on the exposed powder in the end of the fuse with one hand and strike the match-head with the box in the other hand (Figure 90). As a variation of the above method a match-head may be broken off, imbedded in the slit of the fuse, and lighted with another match (Figure 91).

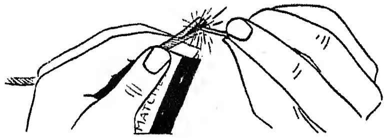


Fig. 91—Lighting safety fuse with flaming match-head

The use of matches is not recommended where a number of fuses are to be lighted at once. Matches involve a number of uncertainties, they do not give a sustained flame of effective intensity, and they are very easily fumbled.

In underground work a carbide head lamp makes a good lighter and is commonly used. The acetylene flame is sharp and hot and gives quick, easy ignition. There is a serious hazard involved, however, if a blaster is touching off a round alone. He may accidentally drop his lamp after lighting several fuses. If the lamp goes out, which it usually does, and the blaster is unable to find it, he must find his way to safety in complete darkness. To eliminate this objection, two men should be present when fuses are being touched off.

For multiple firing the most convenient and safest method of lighting fuses involves the use of one of the fuse lighters described in Chapter V.

FIRING ELECTRICALLY

One of the basic fundamentals of electricity, Ohm's Law, is the controlling factor in properly laying out the wiring scheme of any electrical blast. Briefly, this law states that the current supplied (in amperes) to any electrical circuit will be equal to the potential (in volts) of the power supply divided by the resistance (in ohms) of the circuit. In condensed form:

$$I = \frac{E}{R} \quad \text{where } I = \text{current in amperes}$$
$$E = \text{voltage of power supply}$$
$$R = \text{resistance of circuit in ohms}$$

In other words, if 110 volts are connected across a circuit of 5 ohms resistance, the resulting flow of current in this circuit will be $110 \div 5 = 22$ amperes.

As stated in a previous chapter, an electric blasting cap is detonated as a result of a heating up of its high resistance bridge wire by the passage of current through it. Naturally, the time taken to heat this bridge wire up to a sufficiently high temperature to cause detonation is a function of the current strength; the stronger the current the shorter the time. If the current supplied is weak, heating up of the bridge wire and hence detonation will occur after an appreciable lag. Furthermore, the lag in firing may vary slightly for different caps even if they are given exactly the same amount of current. It is consequently apparent that if several caps are connected up in the same shot and supplied with an inadequate amount of current, some of them may fire slightly before the others and in so doing break the electrical circuit before the slower ones have received enough current to fire them.

With a knowledge of Ohm's Law and also a knowledge of the amount of current necessary to insure practically instantaneous detonation of an electric blasting cap, it is possible to lay out the wiring scheme of a blast in such a manner that all caps will receive a current supply adequate to insure a successful blast.

For the sake of simplicity, the discussion which follows on firing circuits and firing with the several sources of current available is restricted to electric blasting caps. Reference to other electrical firing devices is postponed until after the principles of electrical firing have been described.

There are three types of circuits or connections which are commonly used for hooking up a number of electric blasting caps, namely, series, parallel, and parallel series. The type used depends upon a number of factors, the chief of which is the source of current. The three usual sources of current are blasting machines, power or lighting circuits, and portable generators, each of which has different characteristics.

Series Circuits. This type of connection provides a single path for the current through every cap in the circuit. It is made by connecting one wire from the first cap to one wire of the second cap, the other wire of the second cap to one wire of the third cap, and so on until all of the caps are included in the circuit. At this point there are two free ends left—one

at each end of the circuit. These are connected to the ends of the leading wire, and the leading wire connected to the source of current. Figures 92 to 94 show various methods of connecting one or more lines of holes in series.

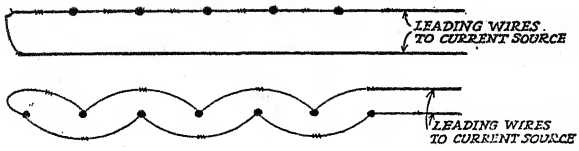


Fig. 92—Two methods of connecting a single line of holes in series

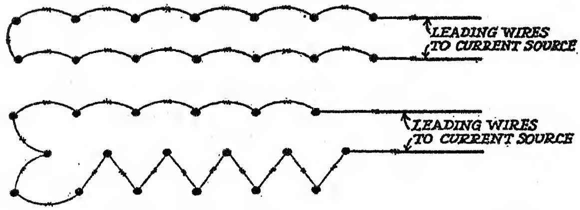


Fig. 93—Method of connecting (top) two and (bottom) three lines of holes in series

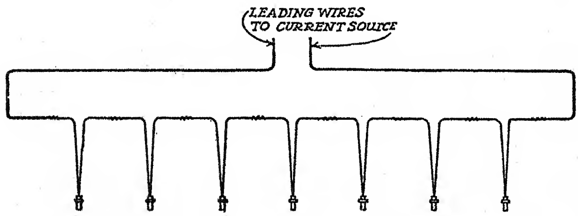


Fig. 94—Another diagram of a series connection

An advantage of a series connection is that it can be readily tested with the circuit tester, and it is possible to tell at any time before firing whether or not there is a break or a poor connection anywhere in the circuit.

This type of connection is almost always used with the blasting machine; in fact, as previously stated, blasting

machines are rated according to the number of electric blasting caps which they will fire in straight series. When shooting with a blasting machine, care must be taken not to overload the circuit, that is, no attempt should be made to shoot more caps in straight series than the capacity of the particular blasting machine which is available. The series method of wiring can also be used with a power or lighting circuit or a portable generator as the source of current.

In the following paragraph is a sample calculation to be made in connection with the firing of 24 electric blasting caps with 8-ft copper wires connected in a series with two 500-ft No. 14 single leading wires. Reference should be made to Tables XII and XIII for data on resistance of various lengths of copper wire electric blasting caps and varying gauges of copper wire.

TABLE XII

Resistance of Regular, Waterproof, and Delay Electric Blasting Caps

LENGTH COPPER WIRES Feet	OHMS PER CAP	
	Regular and Waterproof	Delays
4	1.26	1.04
6	1.32	1.10
8	1.38	1.17
10	1.45	1.23
12	1.52	1.30
16	1.65	1.43
20	1.79	1.56
24	1.93	1.71
30	1.76	1.54
40	1.97	1.75
50	2.18	1.96
60	2.35	2.16

TABLE XIII

Resistance of Copper Wire of Various B. & S. Gauge

GAUGE No.		OHMS PER 1000 FT
2		0.156
4	Heavy-duty power lines	0.249
6		0.395
8		0.628
10	Usual size for power and lighting circuits	0.999
12		1.588
14		2.525
16	Common sizes for leading wire	4.015
18		6.385
20		10.150
21	Connecting wire	12.800
22		16.140

With a series connection the current supplied should be at least 1.5 amperes. The voltage required for any given series can be found by calculating the total resistance of the circuit in ohms and multiplying this by 1.5 amperes. The total resistance of the circuit is equal to the combined resistances of the 24 caps, plus the resistance of twice 500, or 1,000 ft of No. 14 leading wire:

(a) $24 \times 1.38 = 33.12$ $\qquad$ $33.12 + 2.53 = 35.65$ ohms

The voltage required is equal to 1.5 amperes multiplied by the resistance or:

(b) $35.65 \times 1.5 = 53.48$ volts

As this figure represents the voltage drop through the blasting circuit it is evident that these caps could be fired with a 110-volt power circuit or, of course, by a No. 30 Blasting Machine.

The amperage required for firing any type of blasting circuit is a somewhat theoretical question into which a number of modifying factors enter and recommendations aim to allow an ample factor of safety. The blaster should also follow this

principle of allowing generous margins for both amperage and voltage. While it may be shown by calculation, similar to that on the preceding page, that it is possible to shoot a series of 100, 8-ft copper wire electric blasting caps with a 220 volt power circuit, practical experience indicates that the limit is 50 caps, and, usually, the number of caps in a straight series connection fired by this voltage should be held down to 40. When a larger number of caps than this must be fired in a single blast, other types of connections should be used.

Parallel Circuits. This method of connecting differs radically from the series method just described. One wire from each cap is connected to one side of the blasting circuit and the other wire from each cap to the other side of the blasting circuit as shown in Figures 95 and 96. It should be mentioned at once that parallel connections cannot be used successfully with a blasting machine but rather must always be used with a power line or generator.

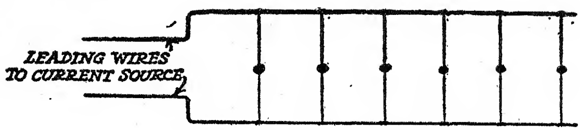


Fig. 95—A method of connecting a single line of holes in parallel

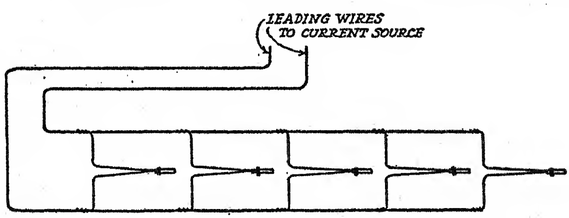


Fig. 96—Another diagram of parallel connections

In this type of circuit it is good practice to allow 0.6 ampere for each cap. The following example illustrates the method of calculating the voltage necessary for straight parallel shots. Assume that a shot consists of 30, 12-ft electric blasting caps connected in parallel at 8-ft intervals to No. 20 connecting wire which is joined, in turn, to two 500-ft No. 12 single leading wires (similar to Figure 95).

Thirty caps at 0.6 ampere per cap will require a total current of: (a) $30 \times 0.6 = 18$ amperes.

When electric blasting caps are connected in parallel, their total resistance is equal to the resistance of a single cap divided by the number of the caps, or in this case—

(b) $1.52 \div 30 = 0.051$ ohms

It will be noted that the actual resistance of the caps is very small; as a result many persons disregard this figure in making calculations and consider the resistances of the connecting and leading wires as the total resistance of the circuit.

Thirty caps connected at 8-ft intervals to No. 20 wire will require $30 \times 8 \times 2$ or 480 ft of No. 20 connecting wire. The exact resistance of wire used in this way can be found only by a very complicated computation. The maximum resistance of these parallel wires, however, will never be greater than the resistance of half their total length and, as the maximum values are the ones that are of greatest importance in preventing misfires, the resistance may be estimated as follows:

(c) $(480 \div 2) \times (10.15 \div 1000) = 2.44$ ohms

No. 12 leading wire has a resistance (Table XIII) of 1.588 ohms per 1000 ft and the total maximum resistance of this circuit is then calculated as the sum of the three resistances—

(d) $0.05 + 2.44 + 1.59 = 4.08$ ohms

The required amperage multiplied by the resistance gives the voltage necessary to fire the shot—

(e) $18 \times 4.08 = 73.4$ volts

It will be seen that it is possible to shoot this round successfully with a power line of 110 volts.

It can also be fired successfully with a 110 volt generator of 18 amperes or more capacity or a 2 kw generator.

(f) $18 \times 110 = 1980$ watts.

Parallel Series Circuits. This method is a combination of the two just described as it consists of joining two or more series of electric blasting caps in parallel. It is usually advisable to use parallel series circuits when more than 50 caps are to be shot with a single application of the current. If the conditions are chosen properly and the hook-up is designed well, there is practically no limit to the number of caps that can be fired in one shot with this method. Under no circumstances, however, should more than 50 caps be hooked up per separate series, and it is better to keep the individual series to 35 caps

or below. Parallel series connections are usually used with power or lighting circuits or portable lighting plants, but with certain limitations they may be used with 30- or 50-hole blasting machines.

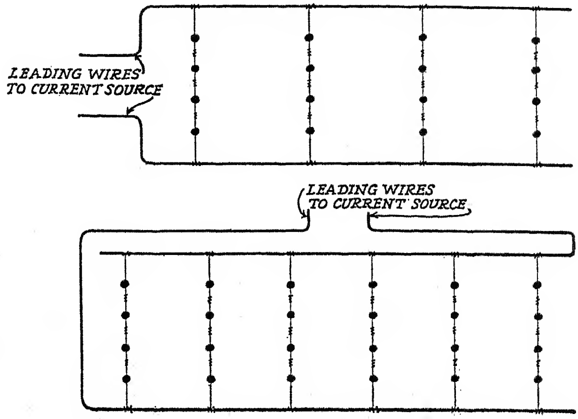


Fig. 97—Two methods of connecting in parallel series

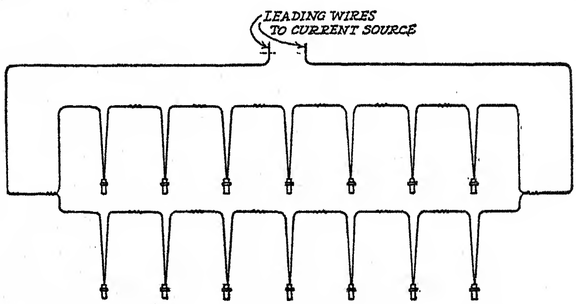


Fig. 98—Another diagram of parallel series connections

In a parallel series circuit, each of the series should contain the same number of caps. Thus, if the proposed shot includes 300, 16-ft caps, it could be divided into 12 equal series of 25 caps each. Assuming that it would require 400 ft of No. 20

connecting wire and 1000 ft of No. 12 leading wire, the power calculations would be as follows:

(a) 1.5 amperes are required for each series

(b) 12 series will require—

$$12 \times 1.5 = 18 \text{ amperes}$$

(c) Each series will have a resistance of—

$$25 \times 1.65 \text{ ohms} = 41 \text{ ohms}$$

(d) As there are 12 series in parallel the combined resistances of the 300 caps is—

$$41 \text{ ohms} \div 12 = 3.42 \text{ ohms}$$

(e) The 400 ft of connecting wire will have a maximum resistance of half its length or—

$$(\tfrac{1}{2} \times 400) \times (10.15 \div 1000) = 2.03 \text{ ohms}$$

(f) The 1000 ft of leading wire has a resistance of 1.588 ohms.

(g) The total resistance of the entire hook-up will be the sum of the three separate resistances or—

$$3.42 + 2.03 + 1.59 = 7.04 \text{ ohms}$$

(h) The minimum voltage required to fire the circuit then is—

$$7.04 \text{ ohms} \times 18 \text{ amperes} = 127 \text{ volts}$$

It is obvious that a 220 volt power line would be required to fire this shot and that any attempt to use a 110 volt circuit would result in the failure of several holes.

The power for the above shot, with a 150 volt portable generator would be—

(i) 18 amp $\times$ 150 v or 2700 watts or 3 kw generator

Figure 97 shows two methods of connecting electric blasting caps in parallel series, differing only in the points at which the leading wires are attached to the connecting wire. The method shown at the top can be used with either a blasting machine, power circuit or a portable generator, but the method shown at the bottom should not be used with a blasting machine except when the total number of caps involved is relatively small.

Connecting Up Wires. A quick method of connecting leg wires consists of placing them side by side, bending the ends to form a short crank and winding them together by turning this crank. This gives a quick, tight connection which becomes tighter if pulled. This connection extends at right angles to the wire but, if it is necessary to tape the joint, this can be

bent alongside one of the insulated wires and the whole taped the same as any other joint.

When it is not necessary to tape wire splices, an effective and quickly made connection is the tight loop shown in Figure 99. Wires should never be joined by a loose, interlocked loop.

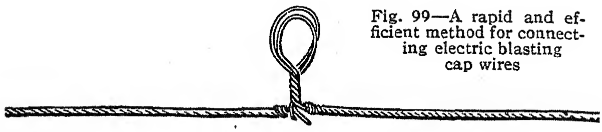


Fig. 99—A rapid and efficient method for connecting electric blasting cap wires

Connections between two lengths of connecting wire or between leg wires and connecting wires must all be carefully made. First the bare ends of the wires should be scraped with a knife blade, and then joined with a long twist (generally known as Western Union twist), such as shown in Figure 100. Such a twist should be made tightly to keep the resistance in the joint down to a minimum.

Fig. 100—Correct method of splicing leading or connecting wires

In making parallel connections using connecting wire, about two inches of the insulation of the connecting wire should be scraped off clean and the leg wires attached by means of a tightly wrapped spiral as shown in Figure 101.

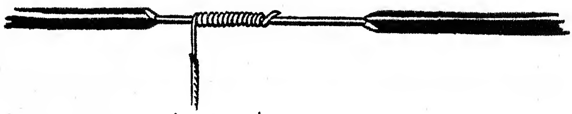


Fig. 101—Method of connecting leg wires to connecting wire in parallel circuits

In connecting detonator wires to leading wires the ends of the wires must be cleaned. The detonator or connecting wire should be wrapped tightly around the end of the leading wire about one inch from the end (Figure 102). Then the end of leading wire is bent back sharply and a turn or two of the

detonator wire is taken around the loop. This last loop is simply to make a stronger connection to withstand any accidental pull on the leading wire that might tear the connection loose.

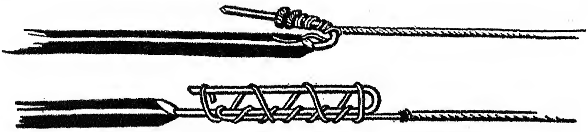


Fig. 102—Methods of connecting an electric blasting cap wire to a leading wire

The bare joints in the wires of a blasting circuit must always be protected against short circuiting on wet ground and especially through water. This is done in several ways. When connections lie on moist ground, they may be held up by supporting them on stones, blocks or sticks, so that only the insulated parts of the wires touch the ground and supports; or the joints may be insulated with tape (Figure 103). While not generally needed where the joints can be held off the

Fig. 103—A properly taped joint

ground, the taping of joints is strongly recommended where the joints are covered by tamping, where they can not be held out of the water on props, and where blasting must be done during a rainstorm.

Testing Circuits. The Du Pont Circuit Tester, described in Chapter V, is used to determine whether the blasting circuit is closed properly for the application of the firing current.

The circuit tester should be tested before being used by placing a short piece of copper wire across its two binding posts. Since the wire has almost no resistance, the needle should be deflected to its widest limit. If the needle does not move entirely across the scale, the battery cell is exhausted or weakened and must be replaced by a fresh one. The simple form of connection makes replacement of the cell easy. *The new cell should always be a silver chloride cell the same as supplied with the circuit tester and not any other type. A flashlight battery must not be used as this type of cell delivers enough current to shoot caps.* The chloride of silver cell is small and light and

can be sent by mail. The length of time a battery cell will last depends, of course, upon how frequently it is used and how long the current is allowed to flow in making each test. When properly used, one cell is sufficient for several thousand tests. The circuit tester can be calibrated by comparing its reading with the resistance of a Du Pont Rheostat.

Although the circuit tester is simple in design and as substantially made as possible for such an instrument, some of the parts are necessarily of delicate construction. It should, therefore, be handled carefully and kept perfectly dry. The latest models are made with moisture-proof cases, but they are not designed to withstand any great amount of water.

The most important use of the circuit tester is for testing a complete series blasting circuit before connecting the leading wires to the blasting machine or firing switch. To make this test, refer to Tables XII and XIII and calculate the resistance of the blasting circuit. Then, from Table XIV find what two posts of the rheostat give the nearest resistance to the one calculated for the blasting circuit. Next connect the circuit tester to these rheostat posts and take the reading. Then scrape the ends of the leading wires clean, connect them to the circuit tester and obtain the blasting circuit reading. If the needle does not move, there is a break in the blasting circuit. If it moves only slightly, there is either a poor connection or a broken wire with the ends just touching. If it swings too far past the reading obtained with the rheostat, there is a short or a ground in the circuit.

To locate a break in the circuit, make sure that the free ends of the leading wire are separated and not touching anything (see Figure 104). Secure a piece of connecting wire, N, to one end connection, D, of the circuit. This wire must be long enough to reach from the joint D to joint C. Hold the bare end of N against the contact post L and touch contact post O to the joint C. If the circuit tester now shows circuit, while it did not when the test was made from the other end of the leading wires, the break is in the leading wires, and they must be repaired. If it does not show circuit, the break is in the electric blasting cap or connecting wires and may be located by touching the contact post O to each of the bare joints, E, F, G, and H, in succession. As long as testing is inside the break, these contacts will cause the needle to be deflected. As soon as the contacts get beyond the break or point of high resistance, either a very slight deflection or none at all will be obtained. In this way the trouble can be quick y

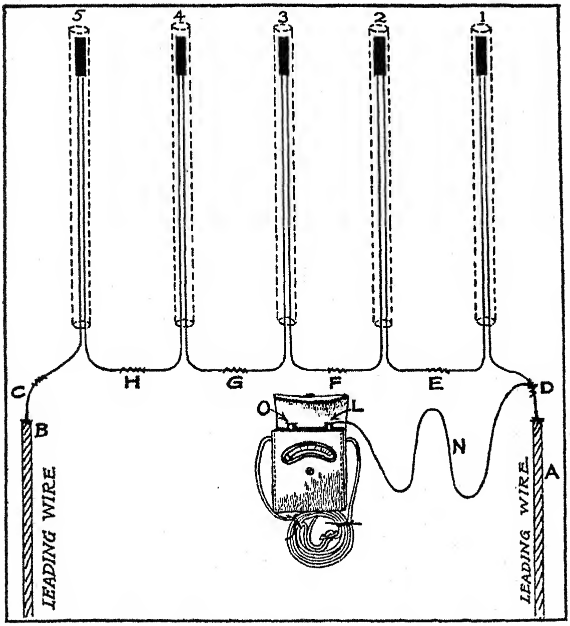


Fig. 104—Diagram showing method of locating break in blasting circuit with Du Pont Circuit Tester

traced to the break or poor joint. For instance, if a wire in borehole No. 3 is broken a deflection will be shown when O is touched to F but none on touching G, showing that the break is between F and G.

If the break is above the tamping it can be easily repaired. If below the tamping and there are two electric detonators in the same charge, the broken one can be left out of the wiring and the hole fired by the good one. If there is but one electric blasting cap in the hole and its wires are broken below the tamping, the hole must be handled as a misfired shot.

The circuit tester may also be used to test single electric blasting caps, both before and after putting them in the borehole. To make this test, the ends of the electric blasting cap wires should be scraped clean and touched to the two contact

posts of the circuit tester. If the needle swings across the scale there is a closed circuit. If it does not swing across, there is some break in the circuit, either in the bridge wire or in a leg wire. It is an excellent practice to test all electric blasting caps after finishing the loading, but before tamping the hole, as well as while tamping, if the tamping is several feet deep.

Firing with Blasting Machines. To operate a Du Pont Twist Blasting Machine the firing handle is inserted in the hole provided so that the slot engages with the cross-piece. The machine is held in the left hand with the wires leading away from the operator, the handle is grasped with the right hand and given a quick, hard twist to the right (clockwise). The quicker the twist, the more current is developed.

To operate the push-down blasting machine it is set squarely on a solid, level place and the leading wires are connected up. The rack bar is lifted by the handle to its full extent, and with one quick, hard stroke pushed down to the bottom of the box with a solid thud, using both hands. ("Try to knock the bottom out of the machine.") As the rack bar approaches the bottom, it becomes more difficult to operate, except with the No. 30 and No. 50 machines, because of the building up of the current; but the speed of the thrust should not be diminished because the finish of the operation is just as important as the start. There should be no fear of pushing the rack bar down too hard. The machine is built to stand it, and this is the only way to use it successfully.

Blasting machines sold by the du Pont Company, though designed as simply as possible, have a more or less complicated and delicate mechanism. They will withstand the usage to which it is necessary to put them, but they must be treated with at least some consideration. There can be no possible excuse for throwing a blasting machine about, or permitting it to remain exposed to wet weather or lying in the mud. When a blasting machine is treated in this way, its life will be short and its usefulness limited.

Good care will prolong the usefulness of the blasting machine, will reduce the necessity for repairs, and will help to maintain its efficiency. The bearings and gearing should be lightly oiled occasionally, but on the commutator, which is the small copper-covered wheel on the end of the armature shaft (see *16* Figure 34) a little graphite is used but never oil. The two slots cut in the copper part of the commutator should be kept clean, and with no particle of metal or anything else in them

which might cause a short-circuit. The copper brushes should be kept clean and adjusted to bear firmly on the commutator. The circuit-breaking contacts should also be kept clean and bright.

When a blasting machine is not in use it should be stored in a dry and comparatively cool place; not in a leaky tool box or on top of a boiler.

Every blasting machine is tested thoroughly before leaving the works. If a new one does not give satisfactory results when received, it is possible that the machine is not being operated properly or has been injured by rough handling during transportation.

Directions for the use and care of the various types of machines are given on a plate fastened to the side of each of the rack bar type machines. *Blasting machine circuits should not be changed in any way for any purpose.* If blasting machines are not functioning properly, they should be sent to the factory for repairs. *No attempt should be made to make repairs locally.*

Every blasting machine should be tested occasionally with a rheostat. If it is necessary to wash out the old oil and clean the blasting machine with gasoline, care must be taken to leave the front and the back open for several hours in order that the gasoline may evaporate before the machine is used; otherwise the explosive mixture of gasoline and air in the machine will be ignited by the spark and possibly wreck the machine and injure the operator.

One way to test a No. 10 Blasting Machine, which has a capacity of ten electric blasting caps, would be to connect ten electric blasting caps in series and then to the blasting machine and operate the machine. If all the electric blasting caps fired, the machine would be working up to its rated capacity; if the electric blasting caps did not fire, the machine would not be up to standard. The results obtained would be absolutely accurate. The objection to this method would be the use of so many electric blasting caps, especially if a No. 100 Blasting Machine were being tested, when one hundred electric blasting caps would be required for the test. This would cause needless expense. The firing of so many electric blasting caps in the open might also be dangerous.

To obviate this expense the Du Pont Rheostat is substituted for all but four of the electric blasting caps connected in two series of two caps each, as indicated in Figure 105. The wires X and Y are connected to the proper posts on the rheostat

to give a resistance equal to the number of electric blasting caps desired.

When such a parallel series connection is made and the blasting machine is operated, if all the electric blasting caps fire, it is safe to conclude that the blasting machine is up to capacity. If one or more of the caps fail, then the blasting machine is not in proper working order. Electric squibs can be used for the test in place of electric blasting caps. Formerly two electric blasting caps or electric squibs in series were recommended for this test but recent experience has shown that the parallel series connection with four caps is a more reliable test.

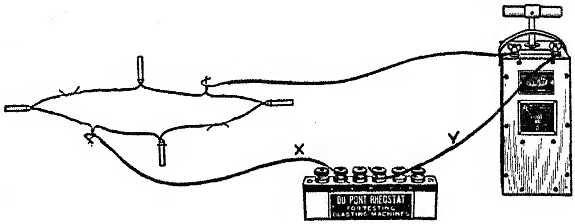


Fig. 105—Testing a blasting machine with a rheostat

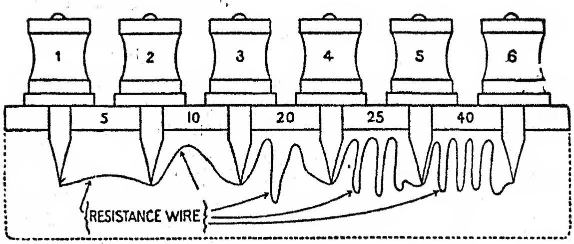


Fig. 106—Diagram of construction of Du Pont Rheostat

The internal construction of the rheostat is shown diagrammatically in Figure 106. It is an arrangement of coils of high resistance wire of a certain length, with the binding posts 1 and 6 attached to its end, and the binding posts 2, 3, 4, and 5 attached to it at intermediate points. The entire length

of the resistance wire in the rheostat has a resistance sufficient to represent a test of one hundred 30-ft electric blasting caps, with a factor of safety to allow for the leading wire, connecting wire, and all connections in the blasting circuit.

It will be noted in Figure 106 that the binding posts 1, 2, 3, 4, 5, and 6, are not attached to the resistance wire at equal distances. The purpose of this is to afford different resistances between different binding posts, each representing a test of a certain number of electric blasting caps. If wires X and Y are attached to binding posts 1 and 2, the test represents a test of five electric blasting caps; if to posts 2 and 3, of ten electric blasting caps; to posts 3 and 4, of twenty electric blasting caps; or to posts 4 and 5, of twenty-five electric blasting caps. But the wires X and Y need not be attached to adjoining posts. If, for instance, they are attached to posts 1 and 4, the test represents the sum of the intervening numbers, five, ten and twenty, or a total of thirty-five electric blasting caps.

By a study of the numbers stamped on the hard rubber between the posts, it will be found that many combinations of tests ranging from five to one hundred electric blasting caps can be easily secured. When it is desirable to make tests, less, by units of five, than is indicated between any combination of posts (say between 1 and 5), the reduction is made by connecting two posts by means of a coin or thick wire. If the wires X and Y, Figure 105, were connected to posts 1 and 5 and a coin inserted between posts 2 and 3, the total of the test would be 60 less 10, or 50.

Should it be necessary to test a blasting machine for ninety detonators, the resistance of ten, between posts 2 and 3, must be blocked out. This is done by connecting these posts by means of a piece of heavy copper wire or a coin. In this way the resistance between any two posts can be subtracted from the total resistance or the resistance between any two posts outside of the two that are blocked out.

The resistances in the rheostat are based on 3.2 ohms per unit of resistance. This is more than twice the resistance of a 12-ft copper wire electric blasting cap. If the electric blasting caps in use are of shorter lengths, it will be possible to fire a greater number than this test will indicate, even, in some cases, up to twice the number. On the other hand, there may be circumstances which will cut down the number that can be fired below what the rheostat test will indicate. Chief among

TABLE XIV

Resistance Between Posts of Rheostat

Between Post No.	Ohms	Between Post No.	Ohms
1 and 2	16	1 and 6	320
2 and 3	32	2 and 4	96
3 and 4	64	2 and 5	176
4 and 5	80	2 and 6	304
5 and 6	128	3 and 5	144
1 and 3	48	3 and 6	272
1 and 4	112	4 and 6	208
1 and 5	192		

these is leakage of electric current in some part of the blasting circuit, either from bare joints or wire touching damp ground or other conductors, or from fluids of great penetrating quality coming in contact with the insulation of the wires for too long a time before firing. If the electric blasting caps differ greatly in sensitiveness to the firing current, this will also cut down the number that can be depended upon to fire simultaneously.

When testing blasting machines having capacities of more than one hundred detonators, two rheostats are used in series.

In some blasting operations it is the practice to test blasting machines and blasting circuits with electric squibs. It must be realized that pieces of aluminum from the squib shell may fly for a considerable distance when the squib is shot and that the same precautions from flying metal must be observed when using electric squibs as are used with electric blasting caps, in order to prevent personal injuries.

Firing from Power Lines. Ordinarily when firing from power lines there is no need to be concerned about the wattage, and hence the amperage available. It is good practice, however, to have fuses in the line to protect against possible short circuits. When such lines are used as a source of current for blasting, the line should be provided with a fuse which will allow the passage of about 100 per cent more current than it is calculated will be required for the blast.

The question of the voltage of the power source is one which elicits frequent discussion. It is sometimes felt that if this is too high, it will burn out the leg wires before the caps have had a chance to detonate. In actual practice this will not happen. The weakest link in any blasting circuit is (purposely) the bridge wires of the blasting caps themselves. Consequently, they burn out before the much larger leg wires of the caps will and in doing so, they naturally will detonate the caps.

However, it is not claimed that extremely high voltages should purposely be sought. High voltages are dangerous to work with from the electrical standpoint. They should not be used in preference to lower voltages if the latter are obtainable. The voltages usually employed in electrical blasting are 110, 220, and 440 volts, while 550 and 660 volts are used on very infrequent occasions. The two lower voltages, i. e., 110 and 220, are considered most desirable from all viewpoints.

Another question which has received a great deal of consideration is the advisability, or otherwise, of using alternating current for the firing of electrical blasts. Theoretically, any building-up effect or change in the intensity of the current should be avoided; it should jump instantaneously to its maximum value when the firing switch is thrown. Consequently, alternating current which is a succession of waves or cycles of changing intensity, from a maximum positive value to a maximum negative value, is a current which is never steady. One would expect, therefore, to encounter misfires in using this type of current for firing electrical blasts.

Such, however, does not appear to be the case. Thousands of blasts have been fired with alternating current of as low frequency as 25 cycle with excellent results. There is no doubt a low limit to the current frequency from which it is possible to obtain good results, however, and since there is little information available on performance of current of less than 25 cycle frequency, it should be avoided. In fact, if it is possible to obtain it, 60 cycle current will provide a higher factor of safety against misfires.

Firing with Portable Generators. If a portable generator is to be used to fire a blast, precautions must be taken to insure that the generator is capable of delivering its rated output the instant the firing switch is closed. The generator should be supplied with a voltmeter and, as an added precaution, it is advisable to connect an electric light bulb across the terminals between the firing switch and the generator.

This light, drawing a small amperage from the generator, provides assurance of the proper magnetism of the field coils (an essential requirement if the generator is of the series-wound type) and also gives visual evidence that the generator is operating satisfactorily before the firing switch is closed.

Additional Precautions. The resistances of du Pont electrical firing devices, other than electric blasting caps and delay electric blasting caps, are given in Appendix I. Normally the number of electric squibs, delay electric squibs, delay electric igniters, and delay electric blasting caps which are fired in one shot is relatively small, and they are wired in circuits exactly as described for electric blasting caps. However, it frequently becomes desirable to use two of these electrical firing devices in a blast, as for example, a combination of instantaneous electric blasting caps and delay electric blasting caps. Since the resistance of these two firing devices is different, care must be taken, when hooking them in the same series, that ample current supply is available. Usually it is preferable to connect up the instantaneous caps in one series, the first delays in another series, the second delays in a third series, and so on, and then to connect these several series in parallel.

While it may be possible to fire the electrical firing devices of different manufacturers in the same circuit when ample current supply is available, this practice is not recommended. In fact, it is far better to follow the rule that electric blasting caps of two different manufacturers should never be used in the same circuit.

One type of misfire that has puzzled blasters has been the failure of center holes in blasts connected in series. Such failures have been most frequently noticed where the holes are wet and the ground water is alkaline or contains mineral salts in solution, or when blasting in sulphide ore. They are likely to occur in blasts where more than 50 caps are connected in series regardless of the amount of firing current available, unless special precautions are taken. Experiments have shown that such misfires are due to leakage of the electric current because of the high conductivity of the soil or water. A portion of the electric current leaks from the cap wires toward the end of the shot, passes around the center holes, and returns to the cap wires at the other end of the shot, and consequently the caps at the ends explode before those in the center receive sufficient current to fire them. Usually misfires from this cause

can be avoided by the use of electric blasting caps provided with enameled wires. In fact, where the ground is highly conductive, as in sulphide ore, it is necessary to use enameled wire caps even in dry work.

When using enameled wire caps it is essential *not to cut the surplus leg wires off*, but to make the connections at the ends of the wires. The enamel has been removed at this point before the caps leave the mill so as to facilitate connecting up. Should a wire accidentally be broken, it is necessary *to scrape off the enamel thoroughly* before making a connection.

Stray currents constitute a potential menace in all blasting operations where power current is used and in mines where the ore is conductive, and in all such operations located near power lines or where electric haulage is used, whether a power current or blasting machine be employed for firing the blasts. Stray currents may leak from any of these sources, enter the blasting circuit, and cause a premature explosion. It should be recognized that stray currents may be of very low voltage or they may have voltages up to the maximum of any voltage used in or near the operation in question. Further, stray currents are not steady; they may come and go, so that testing for them is not conclusive evidence of their presence or absence. Stray currents can be largely avoided by the proper bonding and cross bonding of all rails and pipe lines, but this alone is not sufficient protection against them.

Probably the most important precautions are keeping electric detonators and squibs short-circuited until the moment of connecting them in the blasting circuit, and keeping leading wires short-circuited until the moment of connecting them to the source of current. As previously stated, the du Pont metal foil shielded shunt gives maximum protection for the leg wires of electrical firing devices.

Where two paths are provided for an electric current, the amount of current flowing through each path is inversely proportional to their resulting resistances. Therefore, the best possible precaution against accidents from stray currents is to provide a short circuit in the leading wires that will have a resistance low enough so that practically all the stray current that may enter the circuit will pass through this short circuit instead of through the electric blasting caps in the charges in the face. When the leading wires are very long it is a good idea to break them at one or more places along the line and have a short circuit established at these points. The places

where the short circuits are established should be at such a distance from the face that if a stray current should pass into the circuit as the wires are being disconnected preparatory to making the firing connections and should cause a premature blast, the blaster cannot be injured.

An additional suggestion for electric firing in coal mines, and in other mines where blasting machines are used, is that the firing cable be hung on the timbers by means of staples. This will keep the wires off the ground and the rails and afford a protection against stray electricity. Of course, in underground work where there is a permanent firing line, this should be installed on insulators.

In open work, there is not so much chance that the wires of the blasting circuit will come into contact with bare live wires, charged machinery, or stray electricity; yet, with the growing use of electric well drills and shovels, these hazards are on the increase so that many of the precautions recommended for safeguarding electric firing in underground work also apply to outside operations, especially those as to keeping detonator wires and leading wires short-circuited until they are connected in the circuit or to the source of firing current.

Firing of charges of explosives should not be carried out when a thunderstorm is approaching or during such a storm. Cap wires or leading wires should be short-circuited and all persons should retire to a place of safety. Short-circuiting is a safeguard but it will not prevent the firing of a charge if the wires are struck by lightning.

Occasionally it becomes necessary to blast in close proximity to high tension electric lines. Under such circumstances the leading wires should preferably be strung at right angles to the high tension line and so secured that the blast will not throw the leading wires over the power line.

Sometimes it is necessary to blast near broadcasting stations of high wattage. If the circuit and leading wires are laid in certain positions these broadcasting stations can produce enough induced current in the blasting circuit to fire an electric blasting cap. Precautions should, therefore, be taken when firing electrically within a radius of a mile in the case of the highest, that is, 50,000 watt broadcasting stations. A choke of proper characteristics will eliminate the hazards which attend this type of work and it is recommended that such a choke be provided.

Immediately after a blast the leading wires should always be disconnected from the blasting machine or other source of power and short-circuited. The blasting switch from a power circuit should also be opened and locked in an open position immediately after the firing of a blast. A simple blasting switch for power circuits is shown in Figure 107. A blasting machine may be equipped with a lock so that the rack bar cannot be operated until the key is inserted and the lock turned. When locks are provided for either blasting machines or power circuit switches, the key should be entrusted only to the blaster in charge of the work.

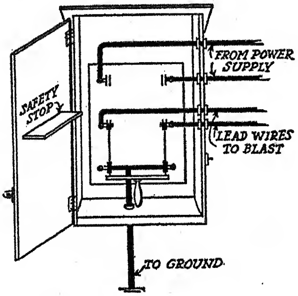


Fig. 107—Safety switch for blasting with power lines which automatically short-circuits and grounds leading wires when in open position

If all or part of the shot fails to go off when the current is applied, be sure to disconnect the leading wires from the blasting machine, or lock the firing switch in the open position before returning to the blast to investigate the trouble. Serious accidents have occurred through neglecting this precaution. Frequently, the failure is caused by a broken connection and if the leading wires are left attached to the power source, correction of the trouble will close the circuit and fire the blast while the investigator is on it.

FIRING WITH "PRIMACORD"

The principal application of "Primacord" is in the detonation of deep well drill holes and coyote shots, where its cost is negligible in comparison with that of the dynamite. It replaces electric blasting caps thus improving the safety of the operation and in cases where many decks are used, greatly simplifies the problem of connecting up. Occasionally where safety is the prime consideration it may be used in short holes, but electric blasting caps would actually be cheaper.

"Primacord" is almost always used for detonating "Nitramon" and this combination makes the safest quarry blasting method that has been designed to date.

Since "Primacord" is a detonating agent throughout its entire length, it primes every cartridge in the charge in contact with it. This insures detonation of the entire charge regardless of the number of decks or units and in spite of the gaps in the column from improper loading or dirt or stone lodged between cartridges. As only one cap is needed to fire the blast regardless of the number of holes or units, there is no excuse for caps on the job until after all holes are loaded and tamped. This eliminates the hazard of unexploded dynamite primed with live caps when a portion of the shot fails to detonate.

Use. Preparatory to loading, a rod or spindle should be inserted through the hole in the center of the spool of "Primacord" and this assembly mounted on an empty dynamite case so that the "Primacord" can be run off the spool easily. The spool should be located close to the drill hole and the loose end attached to the first cartridge in the manner described under priming with "Primacord." Using this cartridge as a weight, the "Primacord" should be allowed to run smoothly and slowly down into the hole. As soon as the cartridge reaches the bottom of the hole, the "Primacord" should be drawn taut to one side where it will not interfere with subsequent loading. If the sun is shining, a mirror will enable the loader to locate the "Primacord" along the side of the hole where it will be least subject to injury during loading. Before loading is resumed, the "Primacord" should be cut off the spool 2 or 3 ft back from the top of the hole, tied around a piece of dynamite box cover and weighed down with a stone so that there is no possibility of it being lost down the hole during subsequent loading and tamping.

After the hole has been completely loaded and tamped, the weight should be removed from the "Primacord," the end raised off the ground and covered with an empty dynamite case or box lining paper to protect it from injury until the remainder of the holes are loaded. Care should be taken to leave sufficient length of "Primacord" outside the hole to allow for any possible subsidence of the charges or stemming. If casings are left in the borehole and these extend above the surface, sufficient length of "Primacord" should be left out of the hole so that it can be looped loosely over the casing without kinking and reach the ground with a little length to spare.

If a break occurs in the "Primacord" during tamping, every effort should be made to remove sufficient stemming to expose at least a foot of "Primacord." This can be primed by dropping

in 10 to 15 lb of loose explosive around the exposed end followed with a 10 to 15-lb cartridge of explosive on a new line of "Primacord." This explosive should be the highest strength available and never less than 40%. Granular dynamite is preferred if the work is dry and cut up pieces of gelatin if the work is wet.

Wire Bound "Primacord" is recommended for the branch lines in all holes loaded with "Nitramon" and in deep, rough holes loaded with explosives. Reinforced "Primacord" should be used for all other holes loaded with explosives and the regular grade will be found perfectly satisfactory for the trunk line.

Splices and Connections. Spools of "Primacord" are not always in continuous lengths of 1,000 or 500 ft but spools containing more than one piece are marked on one end to show the number of pieces, the length of each, and the order in which they will come off the spool. In the case of Plain

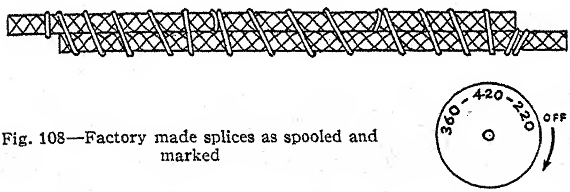


Fig. 108—Factory made splices as spooled and marked

and Reinforced "Primacord" the cut ends are joined with a factory-made splice, while Wire Bound "Primacord" is not spliced at the factory, but rather the ends of the pieces of this "Primacord" are tied with string simply to prevent losing an end down a drill hole. When it is necessary to join two lengths of "Primacord" this should be done with a square knot, as shown in Figure 109. To make this knot with Wire Bound "Primacord" it is necessary to strip the wire countering back for about 8 in. on both pieces.

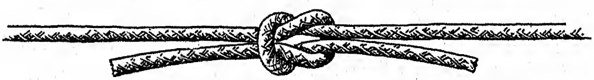


Fig. 109—A square knot for making a splice in "Primacord"

Spliced or knotted connections should not be used in a drill hole unless this cannot be avoided, primarily because water under pressure may penetrate the exposed ends and cause the

line to fail at the splice, and also because the knots may pull apart during loading. If it becomes necessary to use a knot in a drill hole, care should be taken to see that it is in contact with dynamite or above the water level.

Connections from a main or trunk line to a branch line into a drill hole are made with a right angle half-hitch shown in Figure 110. Here again, when using Wire Bound "Primacord" for the branch line, it is necessary to strip the wire countering back about 8 in. before making the connection to the trunk line. It is essential that the right angle be maintained when making these "Primacord" connections since failures have resulted when the angle was much less than a right angle in the direction from which the detonating wave was initiated in the trunk line. The other necessary precaution is to make sure that the connections are kept dry. Although "Primacord" will continue to detonate even if the core is very wet, it must be initiated from a dry end.

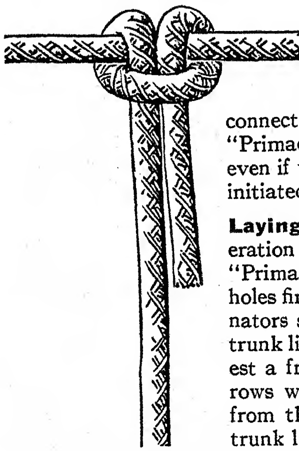


Fig. 110—A right angle connection from trunk line to branch line

Laying Out Blasts. The first consideration in connecting up a blast with "Primacord" is to make certain that the holes fire in the proper order. The detonators should always be placed on the trunk line so that the row of holes nearest a free face will fire first and other rows will fire in order as they recede from the face. Whenever possible the trunk line should make a complete circuit so that every row of holes will have two ways by which the detonating wave can reach it. Rows should not be connected, however, by cross pieces of "Primacord" at positions other than at the ends since this may disturb proper rotation of firing.

Figures 111 to 115 illustrate how trunk lines should be run and where the detonators should be attached in blasts comprising various combinations of rows of holes and in tunnel blasts.

Attaching Detonators to "Primacord." Detonators should not be attached to "Primacord" until all other preparations are completed and the blast is ready to be fired.

The end of the "Primacord" to which the cap is attached should be freshly and squarely cut off and dry.

All connections between caps and "Primacord" should be made with the unions designed for that purpose. There are two types of unions: the *straight* for connecting an ordinary blasting cap, and the *special* for connecting an electric blasting cap. One end of these unions is a solid tube to hold the "Primacord" and the other end is split to receive caps.

If the blast is fired with fuse, an ordinary cap is crimped to the fuse in the usual manner. A straight union is then crimped onto the "Primacord" with the latter extending through the solid tube so that the end of the "Primacord"

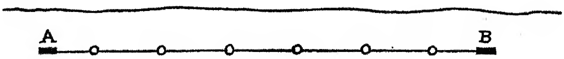


Fig. 111—A single row of holes connected by "Primacord." Trunk line detonated by fuse and cap or electric cap attached to "Primacord" at A or B, or by electric caps at both A and B

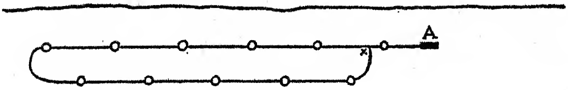


Fig. 112—Double row of holes connected by "Primacord." Note "Primacord" from back line is tied to the trunk line at point X with right angle connection. Detonated by fuse and cap or an electric cap attached at point A

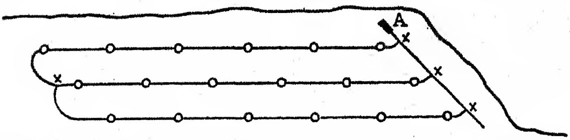


Fig. 113—Three rows of holes connected by "Primacord." Right angle connections at points X. Detonated by fuse and cap or an electric cap attached at point A

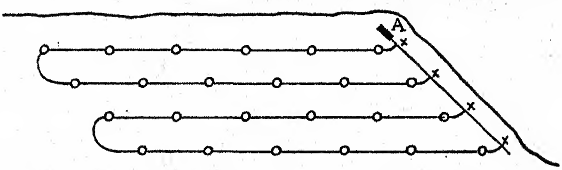


Fig. 114—Four rows of holes connected by "Primacord." Right angle connections made at points X, "Primacord" to be detonated at point A

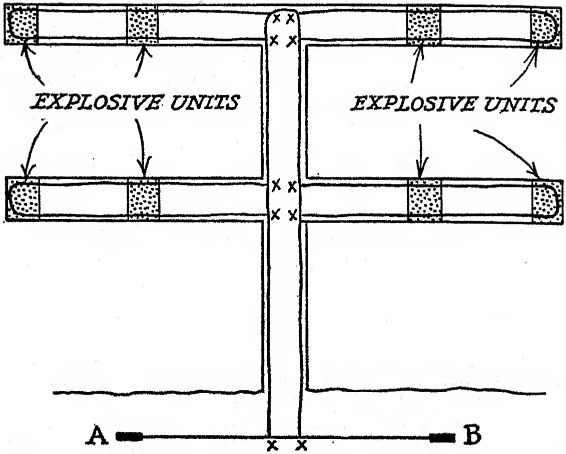


Fig. 115—Method of connecting "Primacord" in priming units in tunnel blasts

comes up to the small hole at the end of the slit. The cap is inserted in the slit end until it seats snugly against the end of the "Primacord." Proper seating can be observed through the hole at the end of the slit. Finally the ring on the union is slid up over the cap end to hold the cap firmly in place. If the "Primacord" is to be fired electrically, an electric blasting cap is attached in a similar manner by the use of a special union. The complete assemblies are illustrated in Figure 116.

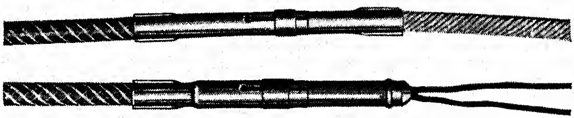


Fig. 116—Blasting cap and fuse (top) and electric blasting cap (bottom) connected to "Primacord" by means of a straight union and a special union respectively

The blasting cap or the electric blasting cap attached to the "Primacord" is fired by an appropriate method as described earlier in this chapter.

CHAPTER XI

BLASTING IN BITUMINOUS COAL MINES

Bituminous coal mines are of three types: (1) drift mines where the coal seam outcrops in a hillside and is entered by a horizontal opening; (2) slope mines where the seam is entered by an inclined opening; and (3) shaft mines where the seam is entered by a vertical opening.

Coal mines are also classified as "open light" or "closed light" mines. An open light mine is one in which no appreciable amounts of methane have been detected and the use of open flame carbide cap lamps is allowed. A closed light mine, on the other hand, is one that is known to be gassy so that it must be inspected by a fire boss and must utilize permissible equipment. Mines may also be classed as closed light mines if they are dangerously dry and dusty, whether or not they are gassy. It should be mentioned also that many mines that are not classed as either gassy or dusty do use closed lights for convenience, efficiency, and safety.

When an underground coal seam has been opened, the development of the mining area must follow a system which is planned with a number of fundamental considerations in mind, such as efficient production, haulage, roof control, and convenience. Three fundamental systems are used in this country:

(1) Room and pillar system in which the working area is divided into rooms separated by pillars of solid coal. Mining by this system progresses in two phases: (a) the "advance" work in which the productive area is developed by a system of entries (to provide access, ventilation, and haulageways) and partially mined out by driving rooms off the entries at intervals along them, leaving the pillars between the rooms; and (b) the "retreat" work in which the pillars are mined out and, as the working area backs out, the roof is permitted to cave in. This system is used largely for both hand loading and mechanical operations. In certain fields it is not advisable, and in others unlawful, to remove pillars since their removal might be followed by surface subsidence.

(2) Block system in which an area is developed in a checkerwork of square or rectangular blocks on a diagonal front so that one side is completely advanced when the other side is started. When the leading side is advanced to the limit of the area, block removal is started and this also is kept on an angle. At first the area comprises all advance work on a diagonal line; then it is part advance and part retreat on an obtuse wedge-shaped front with one side advancing and the other withdrawing; and finally it is all retreat work on an opposite diagonal line. The block system is a special modification of the room and pillar system designed to increase the percentage of coal recovered in seams which carry excessive weight and would otherwise require large pillars.

(3) Longwall system in which the working area is a more or less continuous face, with all of the coal being taken as the face advances and the roof being permitted to cave behind the face. This system is not greatly used but is adaptable to hand loading and mechanical operations, in the latter case particularly to conveyor mining.

Some coal seams have very distinct cleavages. When rooms are driven square on the face a much better grade of coal is produced and with less shooting and digging than when rooms are driven even a small angle, say 15°, off the face. If for drainage or other reasons the entry is driven at an angle other than 90° with the coal face, then, if possible, the rooms should be driven at such an angle to the entry as will put them square on the face. In other systems of mining, consideration should be given to these facts.

Two methods of blasting coal are used, namely: shooting "off the solid," in which, as the term implies, the coal is blasted from the solid seam which usually has but one free face; and shooting "cut coal" in which the coal seam has been previously cut or sheared, or both, in order to provide at least one extra free face. The former method is the older and the only one used for many years in this country. The latter method came into common usage with the development of coal cutting machines and is essentially the only method now being adopted in new mines. Hand loading is practiced almost universally in mines where solid shooting is employed. In operations where the coal is cut, hand loading or mechanical loading is practiced, the latter increasing rapidly. The method of loading, as will be seen in the following discussion, influences the blasting.

All classes of explosives are used in coal mining—blasting powder, pellet powder, permissible explosives, and regular dynamites. The use of regular dynamites is rapidly decreasing and this is as it should be, for they are more dangerous than permissible explosives and there is no kind of work that permissibles will not do with equal or greater efficiency at equal or lower cost, whether it be in the shooting of coal or the rock.

In gassy or dusty mines the use of blasting powder is extremely hazardous. The mixture of gas or coal dust with air constitutes a highly inflammable explosive mixture and the ignition of local pockets of gas or dust from the flame of blasting powder may start a general explosion throughout the mine. Mine fires caused by blasts with blasting powder are a source of great expense and considerable danger.

Pellet powder is likewise dangerous in gassy or dusty mines, but where permissible explosives are not needed it has many advantages over blasting powder. It is safer and more convenient, resists water better, usually makes more lump coal, and is more economical.

Permissibles are the only kind of explosive that should ever be used in a gassy or dusty mine. When they are used in accordance with the conditions laid down by the Bureau of Mines, there is very little likelihood of ignition of gas or dust by the blast.

SHOOTING OFF THE SOLID

In advance work in shooting off the solid there is usually but one free face exposed, but in pillar work or stump extraction there may be two or more free faces. In solid shooting every shot must have a "chance," that is, a free face to which the burden can break. A skilful shooter will keep his place in such shape that shots always have a good chance.

For best results in shooting off the solid, holes should not be drilled at angles greater than 45° to the face. Burdens should be balanced as carefully as possible. Generally holes should not be deeper than the coal is high and the burden should not be more than half the depth of the hole.

Each burden must not only be broken from the solid but also pushed out along the top and bottom bedding planes. Where the partings are good this is not difficult but where they are irregular or where the coal is burned (sticks) to the roof, a strong shearing force is necessary to move the burden

along these planes. The charge should be concentrated as much as possible toward the back of the hole so that the explosive power is behind the burden. Generally large holes should be drilled. The best explosives for shooting off the solid are those

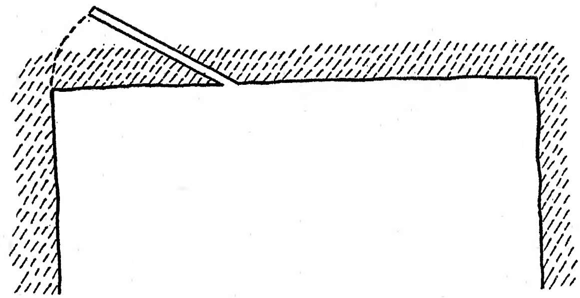


Fig. 117—Shooting coal off the solid

with ability to shear vertically, good heaving action, and the least tendency to break out flat ("flat-crack"). These properties are most pronounced in the slowest explosives.

In the Central Western States where there is considerable shooting off the solid, the slower (C, CC, and CCC) granulations of black blasting powder are most commonly used. The next most common explosives are the slow pellet powders (No. 3 and No. 5) in large (1¾, 2, and 2½ in.) diameters. In other sections somewhat faster black blasting powders (F, FF, and FFF) and the faster pellet powders (No. 2 and No. 4) are employed. By far the largest majority of this blasting and pellet powder is fired by fuse, though in recent years some operations have changed over to the use of electric squibs.

There is also a small amount of shooting off the solid with permissibles, usually the high density "Monobels" and "Lump Coal" C, essentially all in 1½ in. and larger diameters. This type of blasting is not permissible usage and should not be practiced in closed light mines. It is a dangerous type of blasting because of the large quantities of explosives required and because of the ever-present possibility of blown out shots from holes that do not have a proper chance.

On the whole but one and one-half to two tons of coal are produced per pound of black powder, and not much more than this per pound of permissibles.

SHOOTING CUT COAL

In blasting cut coal it is necessary not only to give consideration to the selection of the explosive and the firing of it, but also careful attention must be given to cutting, drilling, and other operations in the mining cycle.

Cutting. With some present-day coal cutting equipment it is possible to cut, to shear, or to cut and shear at practically any place in the seam. The object of cutting or shearing is to expose two or more faces of the burden to be shot. Coal tends to break along vertical and horizontal planes and cutting permits explosives to exert a loosening action that is much less violent than the action of shooting off the solid.

The normal kerf (cut out portion) is 6 in. wide and varies from 4 to 9 ft in depth. In thinner seams 4 in. kerfs are sometimes cut, but these give the coal less chance to break than the wider kerf and are usually not justified. Kerfs vary in shape and the ideal shape is rectangular but cuts in the shape of an arc can be blasted satisfactorily. Poor operation of cutting machines, however, results in cuts that are either gripped or rounded or both at the sides and these interfere with proper blasting of the place.

For best results machine cuttings should always be removed from kerfs before the place is shot. The importance of thorough "bug-dusting" cannot be too strongly stressed. The purpose of the kerf is to give the coal a chance to be displaced. If the dust is not thoroughly removed this purpose is defeated. Shooting onto dust leads to overshooting, poor preparation and unsatisfactory loading.

Most frequently coal is undercut only. In coal that is difficult to shoot properly, that is, high or tough, for example, undercuts are sometimes snubbed. A snub may consist of a second cut widening the kerf to twice or more the width of one cut, or it may comprise merely digging off some of the front edge to produce a deeper kerf. Snubs give the coal more room for displacement when the coal is shot and tend to make it open up and roll out more for better loading.

Top cutting is most often employed to improve roof conditions. It is also used where undercutting is undesirable due to irregularities in the bottom.

Middle cutting is used in high seams for a "benching" effect, in which case the cut is usually nearer the bottom than the top but most frequently its purpose is to cut out large bands of impurities wherever they appear in the seam.

Shearing is a vertical cut used principally to supplement horizontal cuts in more difficult shooting. It is usually near the center of the face but may be in any position between the center and either rib. Shearing is seldom practiced alone without a horizontal cut. Its principal advantage is that the amount of explosive required to shoot a place is less and the shattering effect on the coal proportionately reduced. Shearing often leads to a reduction in the amount of fine coal produced, in spite of the increased amount of cuttings, and improves the proportion of prepared sizes.

Long wall cutting, as the name implies, provides a long straight face of coal up to, in some cases, several hundred feet long. The coal is undercut and shot similarly to a face in a room except that it is easier to shoot because the tightening effect of the ribs is virtually absent.

Drilling. Proper drilling is very important in the blasting of coal. Consideration must be given to the diameter, depth, placement, and condition of the boreholes.

Preparatory to drilling cut coal, it is good practice to measure the depth of the kerf and determine the direction of each hole, using for the purpose a tamping stick, scraper, or bug dust shovel. In no case should the holes be drilled into the solid beyond the back of the cut or into the coal that has not been cut along the ribs. Gripped holes are tight, require excessive amounts of powder to break them and should be avoided. For either permissible explosives or black powder the holes should be drilled as level as possible and parallel to the line of sights, i. e., the direction in which the room or entry is being driven. Holes should be drilled at the maximum distance from the rib at which the shot will trim the rib and no deeper than necessary to square up the face. When using black powder the holes must be drilled closer to the rib than with permissibles.

In best practice one hole is drilled at a time and this is fired and the coal loaded out before the next hole is drilled. Under these conditions each hole can be drilled with the proper burden and the placement of holes is a relatively simple problem. In certain systems of mining and where shooting "off shift" is required, all holes in the face are drilled before any

are shot and under these conditions additional care must be exercised to see that the holes are placed properly.

To permit satisfactory loading, drill holes should be sufficiently large to accommodate the maximum diameter of explosive to be loaded, as smooth as possible, and should be thoroughly cleaned.

Boreholes prepared properly, as indicated, can be shot with the minimum quantity of explosives and will contribute to the production of the best grade of coal.

Charging and Tamping. The charging of boreholes in coal has been specifically mentioned in Chapters VIII and IX. The following additional information should, however, be given.

Most coal miners use more explosive than is necessary. This habit causes increased cost per ton of coal, increases the blasting hazard, and decreases the percentage of coarse coal. In mines where "on shift" shooting is permitted, overcharging can be eliminated by close supervision and proper gauging of the charge in accordance with the burden on each hole. Unfortunately, in "off shift" shooting, overcharging is seldom, if ever, overcome.

Two kinds (grade or make) of explosives should never be loaded in the same borehole. The worst violation of this rule is to load black powder and permissibles in the same hole.

The du Pont Company manufactures for use in coal mines a complete line of explosives of widely different strength, density, size, and velocity, and these can ordinarily be expected to cover shooting requirements. By proper selection of the explosive, the charge can be concentrated in the back of the hole or strung out toward the front of the hole as desired.

Damp clay or sand, or better still, a mixture of the two, in proportions of about 2 to 1, is recommended for stemming. Combustible stemming, such as coal dust or cuttings, should never be used. One or two dummies of stemming should be inserted into the hole and pushed gently into place against the explosive. Subsequent dummies should be tamped solidly to the collar.

When permissibles are used and tamped solidly, there is sometimes excessive pulverization of the coal at the back of the hole or unsatisfactory execution at the front. Under such conditions air spacing or cushioning is sometimes resorted to, if permitted by law. An air space can be provided in one of several ways: that is, the whole charge can be pulled forward from the back end of the borehole to leave an air space behind it; a space can be left in front of the charge between

it and the stemming; or the air space can be left around the charge by using an explosive considerably smaller in diameter than the drill hole. Cushioning provides the same results as air spacing but does not entail the use of an unoccupied space. The most common method of cushioning is to place the first few dummies of stemming against the charge lightly without tamping them, and then finish by tamping the last dummies tightly.

Order of Firing. Figures 118 to 122 show faces of coal in a relatively high seam with various types of cuts and with the drill holes numbered in the firing order generally used in single shot firing. Lower coal or smaller rooms would require a smaller number of holes which would be fired in the order of the first ones shown and, of course, higher coal and wider rooms might require a correspondingly greater number of holes. Figure 121 shows four holes. Very frequently only two holes, No. 2 and No. 4, are required when the face is both cut and sheared.

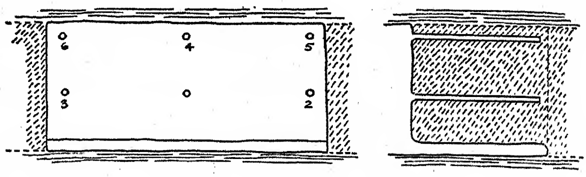


Fig. 118—An undercut coal face

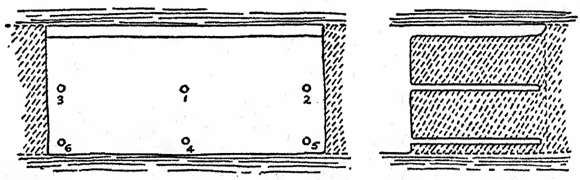


Fig. 119—A top-cut coal face

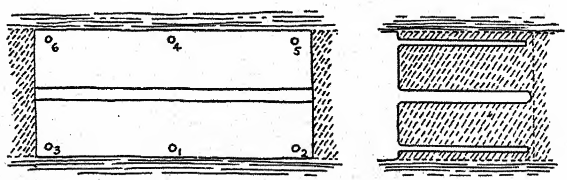


Fig. 120—A face of coal with cut near the center

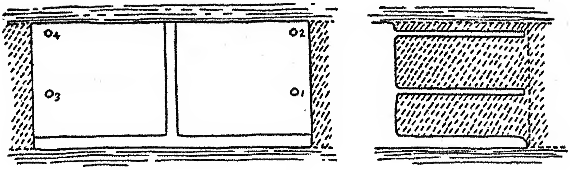


Fig. 121—A coal face undercut and center-sheared

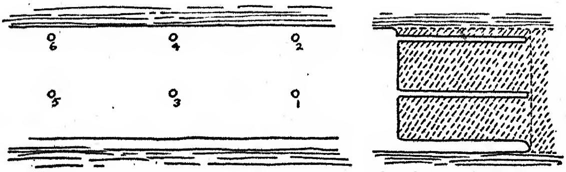


Fig. 122—An undercut longwall face

For many years single shot firing only was approved by the Bureau of Mines. Recently the Bureau has approved multiple firing under certain conditions. One condition which justifies multiple firing exists in mines where it is thought to be safer to fire in multiple than to return to the face to connect up after each charge is fired. The practice of multiple firing is increasing.

Loading Out. In normal times coal for heating homes represents an appreciable percentage of the total bituminous coal production and a maximum amount of "prepared" sizes of coal is desired to satisfy this market. Best preparation requires the use of minimum amounts of explosives—just enough to loosen the coal from the face so that it can be freed with a reasonable amount of digging. When coal is loaded by hand there is little breaking up of the coarse coal and maximum proportions of prepared sizes are obtained.

In recent years, however, mechanization has introduced the factor of production per man and per machine and "loadability" has assumed equal importance with preparation. Loadability requires that the coal be shot so that the machines can load it at their fullest capacity with as little time as possible wasted in digging. Loading machines, particularly the

mobile type, break down coarse coal especially if the coal is tight so that considerable digging is necessary. Hence the shots should be regulated to break up and throw the coal out for easy access. It is evident, therefore, that maximum loadability and preparation equal to hand loaded coal cannot both be had at the same time. The amount of explosive used is very important. Too little powder leaves the shot tight and hard to open up, and too much powder breaks the coal up and compacts it into a tough mass that bridges and wedges so that loading is equally difficult.

Explosives. The description of the uses of black blasting and pellet powder in Chapter I and of permissibles in Chapter II refers primarily to shooting cut coal. Reference should be made to those chapters.

In states requiring off-shift shooting, the average yield of coal is about five tons per pound of permissibles. Where on-shift shooting is practiced, the yield averages seven to eight tons per pound of permissibles, with a maximum in isolated instances of as high as twenty to even thirty tons per pound.

Firing Charges. In years past fuse was used to fire the majority of charges of black blasting and pellet powder but in recent years electric squibs are gradually replacing fuse for firing. Cap and fuse are used with permissibles in certain operations but the amount of such firing is relatively small. This is not permissible usage and is gradually being replaced by firing with electric blasting caps. For firing either electric squibs or electric blasting caps some operations use dry cell batteries but this practice has many hazards. A permissible blasting unit is recommended for either single shot or multiple firing.

BLASTING ROCK

In opening up new coal mines it is necessary to sink shafts or drive slopes or tunnels to reach the coal seam; also in mines that have been worked it sometimes becomes necessary to tunnel through rock for drainage or other reasons. The blasting methods employed in this work are essentially the same as, or modifications of, those described in Chapters XII and XVII. The following, however, is a brief discussion of rock blasting peculiar to coal mines.

Blasting Falls of Rock. The best procedure for blasting large rock that cannot be broken up with a sledge is to drill several

hammer drill holes in it and charge, tamp, and fire them one at a time, using permissible dynamite or gelatinous permissibles.

Firing mudcapped explosives (adobe shots) should never be done in a coal mine. This is one of the most hazardous acts that can be performed in a coal mine and has been the proven cause of several major disasters.

Brushing Top or Bottom Rock. Top or bottom rock should be drilled with hammer drill holes to the desired grade line. The spacing of the holes and the explosive charges required should be determined by trial as they will be influenced by the hardness of the rock and the amount to be taken.

Permissible dynamite or, in hard rock, gelatinous permissibles should be used. The holes should be well tamped with non-combustible stemming. A reasonable number of holes may be shot at once but they should be fired electrically and all with instantaneous caps, not in rotation with delays.

CHAPTER XII

BLASTING IN ORE MINES

Blasting in ore mines is influenced by a wide variety of conditions arising from the type and distribution of the ore, the nature of the rock in which the ore is imbedded, the stage of the mining operation, and the method of mining.

Ore veins vary in thickness from a fraction of an inch in the case of precious metal deposits, to massive veins several hundred feet thick. The ore may be pure and surrounded by country rock, or disseminated throughout the rock. In the mining of thin veins and deposits, the character of the ground blasted is essentially that of the rock. Ores and rocks vary greatly in hardness, toughness, and structure, and the pitch of the veins may be anything from horizontal to vertical.

Mining operations are usually of four types—prospecting, exploration, development, and production. Prospecting involves the location of ores, and exploration the determination of the extent of the ore body. Blasting may or may not be employed in prospecting and exploration, but when it is, the methods follow those employed in other operations described in this book, and, therefore, are not discussed here. Development is the work involved in providing access to the ore and in providing for systematic removal of the ore body, transportation, and ventilation. Production comprises the removal of the ore on a commercial basis. Blasting in development and production is discussed in this chapter.

DEVELOPMENT

Development operations consist of drifting and crosscutting, raising, and sinking. These differ from the usual tunnelling and shaft sinking operations only in that they are frequently smaller in cross section and that less emphasis is laid on the speed of advance. Development headings are advanced by drilling a complete round of boreholes and blasting them so that the entire face of the heading is broken out approximately to the depth drilled.

Boreholes are usually drilled with air-driven hammer drills mounted either on vertical columns or horizontal bars. Most

of the modern air drills are designed to drill wet to minimize dust and to cool and lubricate the bits. Air drills also aid in ventilating the working headings, as they use and exhaust large volumes of air.

Blasting in an underground development heading is always tight. There is only one free face to which the ground can be broken and this is usually of limited size. The first and most difficult step in blasting any heading is to make an opening into the solid ground, usually in the center of the face and as deep as practical to advance the face at one time. This opening is called the "cut" and although cuts may be pulled by a number of methods of drilling and blasting, they all serve the same purpose, namely, to form a second free face to which the remainder of the holes in a round can break. It is therefore obvious that the cut is the most essential part of the round as the rest of the holes cannot possibly pull, unless the cut comes out completely. A few extra minutes spent in directing the drilling of the cut holes may easily mean the difference between pulling a good full round every shot or frequently obtaining only one-half the anticipated advance.

Rounds consist of (1) the cut holes, (2) the relief holes, and (3) the trim holes. These three types of holes are fired in rotation, the cut holes to make the initial opening, the relievers to make the enlarged opening, and the trimmers to square up the face to its full desired dimensions.

Types of Cuts. The V or wedge cut is one of the oldest and still most commonly used. It consists of a pair of holes drilled so as to meet or practically meet at their bottom to form a "V," or two or more pairs of V's in parallel planes to form a wedge (Figure 123). V-cuts in drifts may be horizontal or vertical, the type selected commonly being the one allowing the wider angle to be drilled. Usually bar drill mountings are used for the former type and column mountings for the latter. In deeper drilled rounds or in very hard rock cuts may consist of double V's (Figure 124), the outer and shallower V-cut being known as the "buster" or "baby" cut.

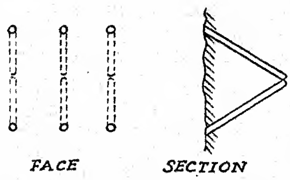


Fig. 123—Typical V-cut or wedge cut

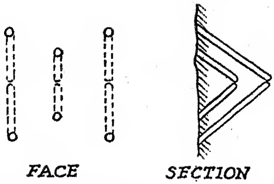


Fig. 124—Double V-cut showing "baby" cut

A modification of the V cut known as the "draw cut" is shown in Figure 125. It is located away from the center of the face and often the holes are purposely drilled so that they do not meet. The bottom draw cut illustrated is most common, although it may be located at the top or side of the round. It is particularly useful in small headings, (less than 6 x 6), where drilling must be done with unmounted hammer drills, and where, due to lack of room it is difficult to drill a cut in the center of the face.

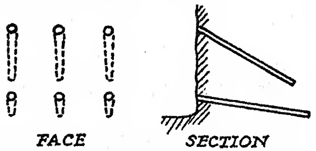


Fig. 125—A draw cut

The cut which is probably next in popularity to the V-cut is known as the pyramid or diamond cut. This consists of three to six holes drilled to meet at a single apex near the center of the face (Figures 126 and 127).

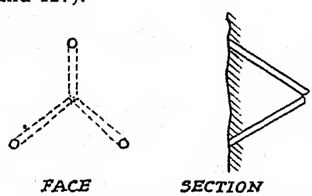


Fig. 126—Three hole pyramid cut

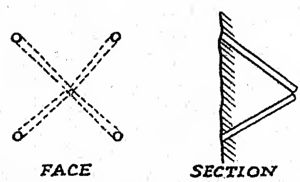
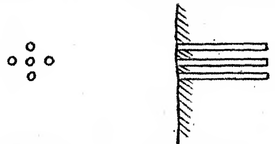


Fig. 127—Four hole pyramid cut

After a little experimentation, it is usually possible to fire the entire round without returning to the face when using any of the abovementioned cuts. This greatly expedites the operation as the miner is not obliged to wait for the smoke to clear up after the cut has been fired so that he can return to the face to load and shoot the remaining holes.

Another frequently used cut is the "burn" cut, known also under the name of "burn out," "Michigan," "Cornish," and "shatter" cut. There are many variations of this cut, but all utilize the same principle. Unlike the V or pyramid cuts which are designed to break out a wedge or cone of rock, the burn cut

is intended to shatter and pulverize a small section of rock which can be scraped out if not already expelled by the blast, to leave a roughly cylindrical opening approximately perpendicular to the face. This cut consists of three or more holes all drilled in a closely spaced pattern (Figure 128) perpendicular to the face and as nearly parallel to the line of the drift as possible. One or more of the holes is not loaded, but is present in the round to provide space into which others can break. Also at least one hole must be loaded to the collar, since if this is not done, the collars of the holes may remain intact even though the cut may be broken inside, in which case there is seldom anything that can be done except to drill and blast a new cut. One disadvantage of this type of cut is that it is always necessary to return and make certain that the cut is completely out before firing the relievers and trim holes.



FACE SECTION

Fig. 128—A common type of burn cut

Types of Rounds. It is usually impractical to attempt to pull more ground per round than the minimum dimension of the drift, that is, the average advance per shot in a 5 x 7 drift will normally be not more than 5 ft. However, it is possible to increase this advance considerably by use of the burn cut already described. In fact, the ground pulled per round with this cut is usually limited only by the amount of muck that can be handled in the available mucking period.

In V-cut rounds, each pair of cut holes forming one V, and in pyramid cut rounds, all the cut holes should fire together. Hence when firing with fuse and caps they should preferably be drilled so that they meet or are close enough together at the toe so that they will propagate. Since accurate drilling is far from generally practiced, all holes should be primed. When firing electrically, simultaneous detonation of the cut holes can be assured with instantaneous electric blasting caps.

In a V-cut or pyramid cut round, the cut is frequently thrown a considerable distance from the face and damages or knocks down the timbers in a heading which must be timbered close to the face. To overcome this, a burn cut is sometimes used. In other cases the cut holes are purposely drilled without a definite pattern such as a V or pyramid cut, but rather with the purpose of blasting material from the face in such a direction that the timbers are unaffected.

The number of cut holes used regardless of the type of cut chosen increases with the size of heading and with the toughness of the material to be blasted.

In small headings one set of relievers is frequently sufficient to enlarge the cut so that the trimmers are not overburdened. In larger headings or tough ground, however, two, three or more sets of relief holes may be necessary to provide progressive enlargement up to the burden that the trimmers can finally break.

It is the usual practice to drill the cut holes in any round so that the point at which they meet is a little beyond the ends of the relievers and trim holes. This makes it a little easier for the other holes to pull to the bottom. The first relief holes should be drilled at a slightly greater angle to the face than the cut holes and normally should not have more than 2 ft of burden at the toe or bottom. The position and direction of the remaining holes of the round should be planned so that the shot will break out in an orderly manner, and care must be taken to see that no hole has an excessive burden

The order in which the various relief and trim holes fire after the cut is of great importance if the round is to pull successfully. As a general rule, the inner relief holes should fire first and the corner relief holes should not go until the adjacent holes, which tend to bind them in, have fired.

The trim holes are usually fired in rotation to give the best squaring up of the face and the desired throw. For mucking by hand or with scrapers the lifters or bottom holes are loaded heavily and fired last in order to throw the material away from the face, while with machine mucking, the top holes are usually fired last in order to pile the material up at the face. Here again, the corner holes must fire last.

The following sketches attempt to show typical rounds of various types. It is impossible to show rounds which will fit all underground conditions because they vary so widely due to the different types of material blasted, the size of the opening desired, the equipment available, and the type of explosive used. It is believed that these diagrams may give the operator a working knowledge of the type of round that should be used in his operation. The actual number of holes necessary and their direction and depth can only be determined by actual experience.

Drifting. Drifts and cross cuts are horizontal tunnels of varying cross section but usually much smaller than railroad or

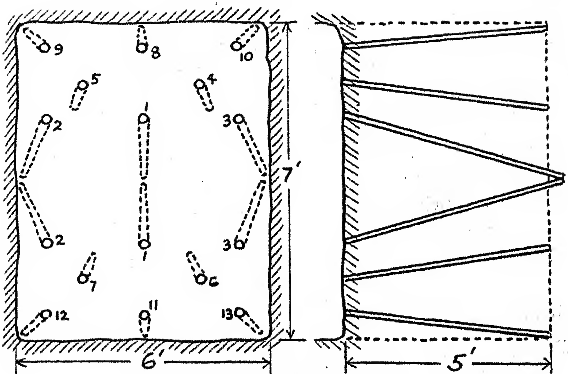


Fig. 129—Horizontal V-cut round

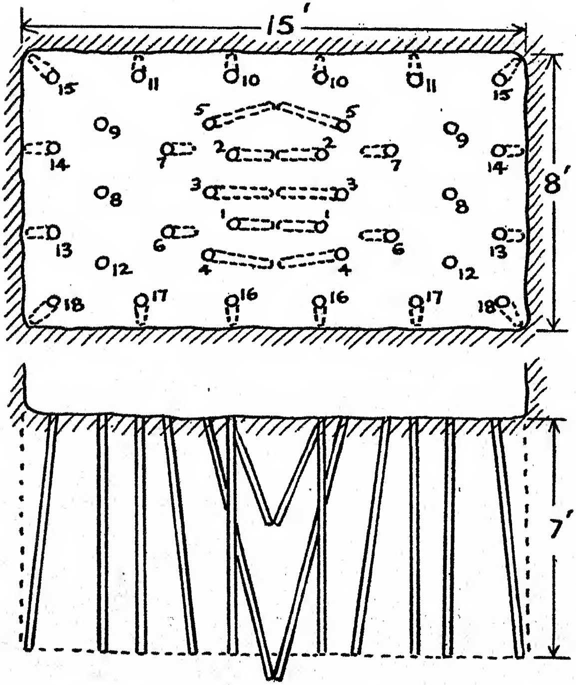


Fig. 130—Wide drift round showing vertical double V-cut

vehicular tunnels. They may be driven for haulage or venti lation purposes. As a general rule they are shot with cap and fuse although this method is being gradually replaced by electrical firing.

Figure 129 shows a typical drift round in medium hard rock using a six hole horizontal V-cut. This round was designed for firing with cap and fuse and the figures by the holes denote the order of firing. The pair of cut holes in the center should go first, then the pair on either side, after which the relievers and trim holes go as indicated.

A large drift round in hard rock is shown in Figure 130. Here a double vertical V cut is used and again the figures indicate the desired order of firing. As this round contains thirty-six holes, it would not be safe for one man to attempt to light the entire round. This is definitely a two-man job and the corresponding holes on either side of the center are marked with the same numbers to indicate the order in which each man would light his half of the shot.

The bottom draw cut round (Figure 131) is very useful in drifts 5 ft by 5 ft and smaller and in thinly stratified material.

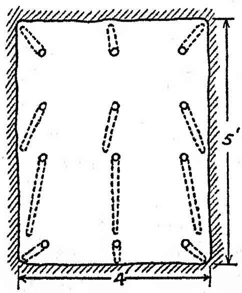


Fig. 131—Drift round using bottom draw cut

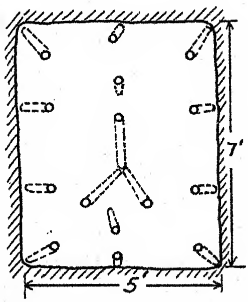


Fig. 132—Three hole pyramid cut round in medium hard rock

In the latter case it is frequently unnecessary to drill the bottom row of holes.

Figures 132 and 133 show three and four hole pyramid cut rounds for use in medium hard and hard rock respectively.

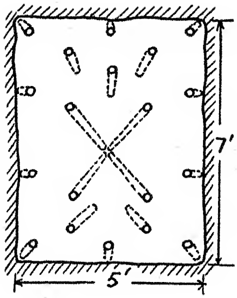


Fig. 133—Four hole pyramid cut round in hard rock

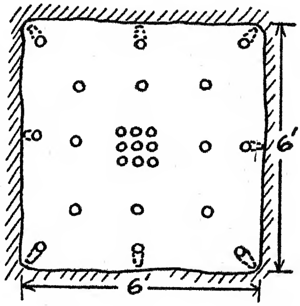


Fig. 134—Nine hole burn cut round

The additional holes in Figure 133 are necessary because of the hardness of the rock.

A nine hole burn cut round is shown in Figure 134. In this particular cut only the four corner holes are loaded, the other five holes merely furnishing space into which the loaded holes may break. Two sets of four relievers are required to open this round up before the trim holes go. As previously mentioned it is necessary to make sure that the cut has pulled completely before attempting to shoot the other holes.

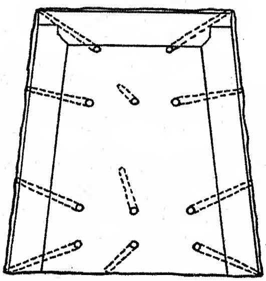


Fig. 135—Round for soft ground timbered close to the face

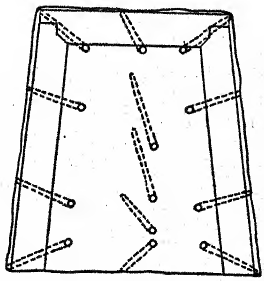


Fig. 136—Round for medium ground timbered close to the face

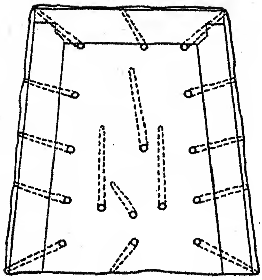


Fig. 137—Round for closely timbered hard ground

Figures 135, 136, and 137 show typical rounds for a 5 ft by 8 ft drift in ground which requires timbering close to the face. The rounds shown are for soft, medium, and hard ground respectively. Note that in every case it has not been advisable to drill a true cut because of the possibility of damaging the timbers. A series of from two to four steeply slanting holes achieve the same result by gradually taking off slabs in the center of the face.

Raising. Raises, as the name indicates, are small passages driven from a lower level to a higher level. They may vary in inclination from vertical to nearly horizontal and, of course, all drill holes will be pointing upward. They are frequently driven to form chutes from the haulage to the grizzly level, or between, say, the grizzly and the mining levels. They may also be driven for drainage, ventilation, and other purposes. It is necessary to build a platform for the men to drill from and ordinarily this platform is left in place during the shooting to catch the ore and control its descent to the mucking level. All raises should be and usually are shot with electric blasting caps and delay electric blasting caps as they are ordinarily inclined at such a steep angle and are so small that descending a raise after lighting the fuse is very hazardous. When electrical firing is used there is no need for the blaster to hurry down the raise after connecting the holes and no possibility of his being caught in the raise while the shots go off.

There can be practically no natural ventilation in a raise and it is, therefore, imperative that the powder fumes be well blown out by compressed air or fans before the men return to muck or drill another round.

Figure 138 shows a typical raise round in moderately haıd rock. The four pyramid cut holes should be fired with instantaneous electric blasting caps, the four relievers with first delays, the four center trim holes with second delays, and the four corner trim holes with third delays. It is possible that all sixteen holes could be shot with instantaneous electric blasting caps and the round pulled satisfactorily but it is better to use delays as it puts less strain on the platform catching the muck.

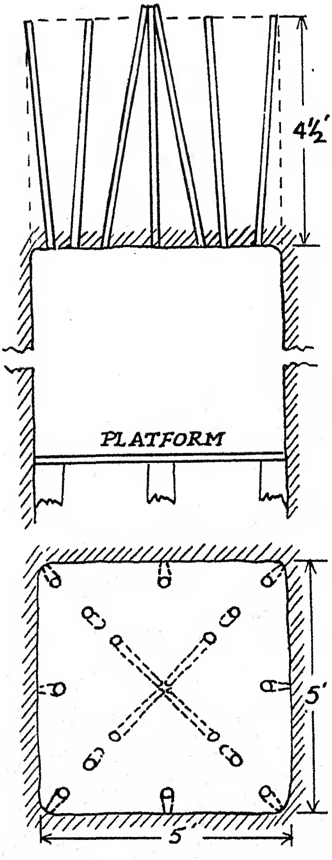


Fig. 138—Raise round in solid rock

Sinking. Shafts and winzes are passageways sunk from one level to a lower level. Shafts are normally sunk vertically and in a straight line as they are usually used for raising and lowering material. Winzes are almost always inclined and seldom straight. They are used for exploration, ventilation, or manways. It is strongly recommended that electrical firing devices be used as it eliminates the possibility of the blaster being caught by the shot before he has been able to reach the top of the shaft or winze.

Figure 139 shows a very satisfactory type of shaft round for small shafts. It does not utilize the usual wedge or cone type cut but makes use of a principle known as a "sumping" cut, in which each round forms a sump to collect the water so that it can be pumped out easily and leave a relatively dry bench on

which the men can do their drilling. This type of round is almost a necessity in very wet work.

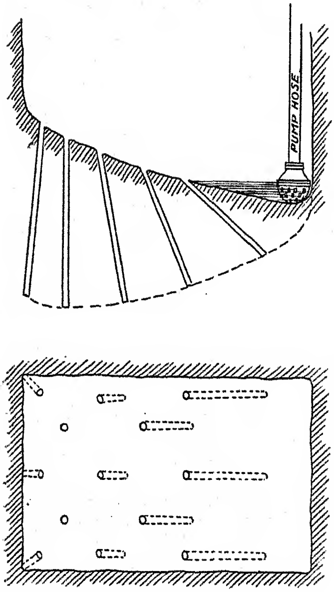


Fig. 139—Small shaft round with sumping cut

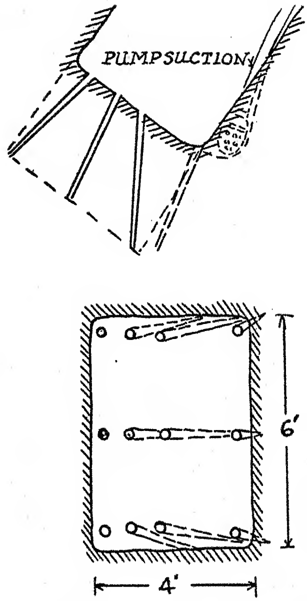


Fig. 140—Winze round using draw cut

Figure 140 shows a winze round using a draw cut. This type of cut is very practical if the winze happens to run along a vein or slip. If there is a free parting at this point it is usually unnecessary to drill the holes along the bottom, although it is advisable to put in one of the lower corner holes and shoot it last in order to furnish a sump.

PRODUCTION

Production includes many phases in the operation of a mine but only those in which explosives are needed will be considered. Blasting is primarily used to break the ore loose from

the main body in a form which can be economically handled. The method followed will depend upon the characteristics of the ore body, the type and value of the ore, the mining system used, and many other conditions which need not be mentioned here.

It is not possible to classify the various mining methods with any degree of accuracy as they have all been designed to fit a specific set of local conditions, and two or more methods may be so combined in one operation that strict technical nomenclature is out of the question. However, they may be very broadly, though inaccurately, separated into two classifications, stoping and caving. Stoping covers all methods which involve blasting rock in or into rooms, holes, caves, etc., on a production basis; and caving includes those in which a part of the ore body is undermined and allowed to fall of its own weight, or systems in which the overburden is allowed to cave progressively as the ore is sliced from the top. For a complete description of open, timbered, filled, and shrinkage stopes the reader is referred to standard works on mining engineering.

Stoping. Regardless of the kind of stope used, the method of breaking the rock usually falls into one of three classifications, although here again the phraseology is not clearcut as the drilling and blasting procedures are determined by local conditions.

(1) Breast Stoping. In this method the ore is broken by flat or slightly inclined holes drilled in a vertical face of considerable area which is advanced in a virtually horizontal direction. This method resembles that of advancing the face of a very wide drift and is used in both room and pillar work and shrinkage stoping.

(2) Underhand Stoping. Here the ore is broken in horizontal slices in descending order similar to that used in quarrying by the benching method. The holes may be drilled vertically downward to break the ore off in slices, or they may be drilled horizontally as lifters at the bottom of each bench.

(3) Overhand Stoping. In this type of shooting the ore is broken in horizontal slices in ascending order with the miners working beneath the ore. The drillers usually stand on the broken ore from previous shots and point the holes vertically upward or horizontally. This type of mining is also called "inverted benching."

Stope blasting is usually much easier than that encountered in advancing development headings. The burdens, as a rule,

have two free faces so the holes can be drilled in one face and roughly parallel to the other. In rotation rounds there is no cut to break. The first holes to fire have free faces and each succeeding hole has a free face established by the preceding holes. The rounds are often referred to as "slicing" or "slashing" rounds as opposed to cut rounds in development.

Figure 141 shows a typical group of breast holes such as might be used in overhand or shrinkage stoping. This particular grouping would be satisfactory for a round approximately 15 ft wide. The two center holes in the bottom row should fire first, then the two rib holes, followed by the two center holes in the second row, and so on, until the round is completed.

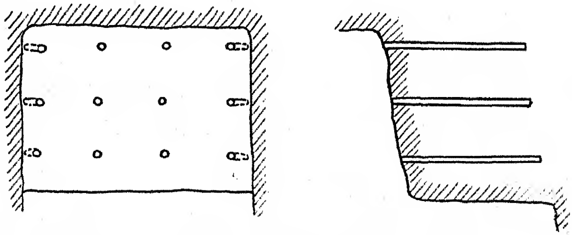


Fig. 141—Overhand stoping using breast holes

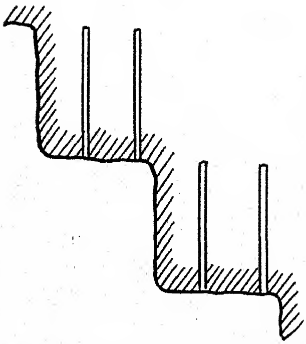


Fig. 142—Overhand stoping using upper holes

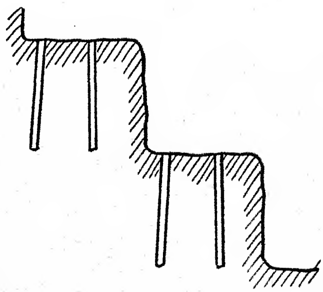


Fig. 143—Underhand stoping using down holes

A typical overhand stoping round, using holes pointed vertically upward, is shown in Figure 142. The holes toward the free face should be fired first, and the rib holes last.

A similar type of round designed for underhand stoping and using holes drilled vertically downward is shown in Figure 143. Here also the holes nearest to the free face should fire before the rib holes.

Figure 144 gives a cross section of two successive slabbing or slicing rounds. These may be used to break ore from the side or from the roof. The slab or slice marked "A" must be shot before the one marked "B" can be drilled.

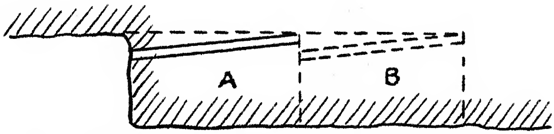


Fig. 144—Slabbing or slicing rounds

The rounds shown in Figures 141 to 144 inclusive are normally shot with cap and fuse although there is a growing tendency to use electrical firing in this work.

Long Hole Blasting. The practice of drilling and blasting long holes in various types of stoping is increasing. These holes are drilled either with hammer drills and sectional steel, or with diamond drills, and in many cases successful use is being made of holes considerably over 100 ft in depth. While the drilling cost may be high, it is offset by the elimination of benches, bench cleaning, and the reduction of hazards due to mining in poor ground. Such holes may be drilled in any desired direction from straight down to straight up. It is, of course, no particular problem to load the downward pointing holes, and the loading of long uppers has been considerably simplified by the use of tamping sticks made of wooden sections held together by sections of air hose or strung on a rope. With this type of tool the tamping stick can be folded up or coiled on the floor as it is withdrawn from the hole. Rounds making use of long holes are usually fired with electric blasting caps or a combination of electric blasting caps and "Primacord."

Figure 145 shows a typical diamond drill stope blast used in benching in an open stope. This type of round has been used successfully with holes up to 140 ft deep.

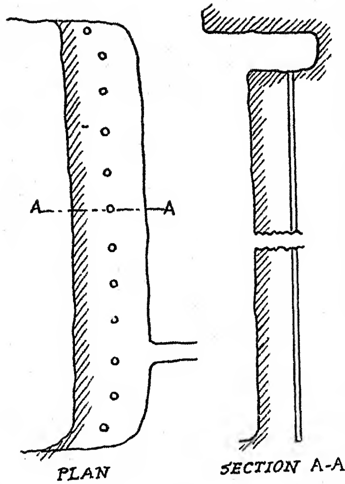


Fig. 145—Benching with long holes

A shrinkage stope breast with long diamond drill holes is shown in Figure 146. This is designed to be fired with electric blasting caps. The three center holes in the lower row should be fired with instantaneous electric blasting caps, the two end holes in the same row with first delay electric blasting caps, the three center holes in the upper row with second delays, and the two upper corner holes with third delays.

Caving. Caving methods of mining involve blasting practices common to both development and stoping. Undercutting requires the driving of a system of drifts, crosscuts, and raises to weaken the area to be caved, leaving it supported by pillars. Final caving is started by

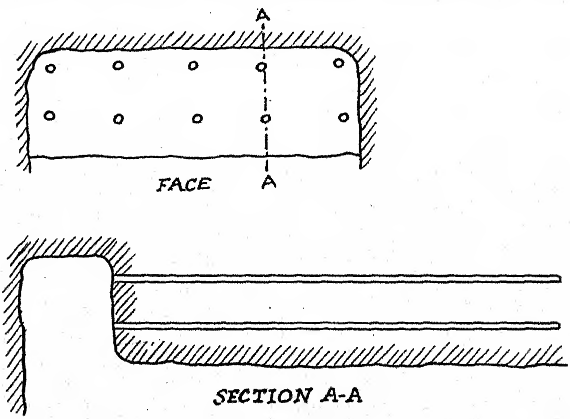


Fig. 146—Overhand stoping with long holes

shooting out the pillars by rounds similar to those described in stope blasting, or by coyote shots in drifts, splitting the pillars. This last method is described in Chapter XIV.

Chute and Grizzly Blasting. When large rocks block the chutes it is necessary to blast them by mudcapping, blockholing, or placing a primed cartridge of dynamite on a stick and bracing it against the rock. Electric blasting is safer for any of these types of shooting than the use of caps and fuse as it is always possible for the blaster to be in a place of safety before the charge is exploded.

Oversize material caught on grizzlies must frequently be shot to prevent stoppages. This is accomplished either by blockholing or mudcapping. Both cap and fuse and electrical methods are used, but the latter method is safer as the timing of the blast can be accurately controlled.

Explosives. Development work is carried out in a comparatively confined space and hence it is highly desirable to choose an explosive that has good fume characteristics. 40 to 60% Du Pont Special Gelatins and "Gelex" No. 1 and No. 2 are usually used in drifting, raising, and sinking, as these types are strong and dense enough to give the high concentration of energy necessary to pull the cuts in tight work. They are highly water resistant and plastic enough to load and "stay put" in uppers and their fumes are the best obtainable.

Stoping operations are more open and are often more easily ventilated than development work, but a dynamite with good fumes should be selected. Except in very hard rock or very wet work, Special Gelatin is seldom required. "Gelex" No. 1 and No. 2 are very popular, and in easy breaking ore where the work is dry, the Du Pont "Extra" grades B to F inclusive, in special wrappers, find wide application.

Special Hazards in Lead and Zinc Mines. Because of the formation of the ore-bearing rock in some lead and zinc mines, the borehole may be closed by falling boulders. If this happens when the hole is partially loaded, an attempt should be made to push the boulder aside with a wooden tamping pole and not with any type of metal implement. If the boulder cannot be moved, it is best to place a primer against it and shoot it. There is so much hazard in loading primers in the irregular holes of this type that special protection is recommended for them.

CHAPTER XIII

BLASTING IN VARIOUS TYPES OF MINES

This chapter deals with the mining of non-metallic materials such as anthracite coal, limestone, clay, gypsum, salt, and talc. While mining methods may be similar to those employed in the removal of metallic ores, the blasting methods are usually quite different, as these minerals are normally softer than most ores and much more prone to occur in definite seams like coal. In fact, some are blasted by systems very similar to those used in bituminous coal, discussed in Chapter XI.

There is not space to consider all of the minerals that are mined in this country, so an attempt has been made to cover only those utilizing the most representative blasting methods.

ANTHRACITE COAL

Anthracite coal usually occurs in seams that vary from about 2 ft to more than 50 ft in thickness and from horizontal to absolutely vertical in pitch. Consequently anthracite mining involves a great variety of mining and blasting practices Occasionally this material may be found in flat, uniform seams similar to most bituminous coal and under these conditions the mining methods followed will be similar to those used in bituminous coal (Chapter XI).

Pitched seams are developed through main gangways which, as a rule, are driven horizontally through coal and of sufficient width and height for haulage equipment. If the seam is thin, some rock may be taken with the coal. Monkey headings which serve as return airways are driven in the coal above and parallel to the main gangways after which the headings and gangways are connected by chutes. Breasts which correspond to rooms in the horizontal seams are driven off the monkey headings with the vein. Breasts vary in width according to roof conditions and they are worked in a manner similar to that of shrinkage stopes in ore mines.

Pillars between breasts are removed by splitting with a narrow pillar breast and shooting out segments by pillar holes drilled longitudinally through or diagonally into the segments.

Sometimes the gangways are driven in rock beneath the seams (rock gangways) and enter the coal seam through rock holes driven diagonally upward. Other rock work includes rock tunnels which may be driven to connect basins. The blasting methods employed are similar to those used in drifting and raising in ore mines.

Anthracite coal is usually shot either with a relatively low density, low velocity permissible dynamite such as "Monobel" C, D, or E, or with a medium fast, low density pellet such as Pellet Powder No. 4. It is also the usual practice to charge several holes at once and fire them in rotation by means of Delay Electric Blasting Caps or Delay Electric Squibs or Igniters. 60% Special Gelatin, "Gelex" No. 1, and "Gelex" No. 2 are usually used in driving rock gangways and tunnels.

LIMESTONE

The underground method of working limestone has three principal advantages. It avoids the expense of removing overburden, it produces clean stone, and it permits operations to go on throughout the year without regard to weather. While the cost of blasting underground is ordinarily higher than in open quarries, this is more than balanced by economies in other directions and some properties where conditions are favorable report an explosives cost comparable with that of open pit operations. It is usually necessary for the stratum to be at least 10 ft thick to permit economical removal, and drilling and blasting costs decrease quite rapidly with increased height of face. From 1½ to 2½ tons of rock per pound of explosive is fairly representative of results in existing operations.

Most underground quarries are developed from side hill tunnels and work the material in a horizontal plane, although limestone deposits are being mined on a pitch, the work being carried on from a shaft and to a depth of as much as 600 ft. In the horizontal deposits it is customary to follow a room and pillar system using either a top heading and bench, bottom heading and stope, or working the full face by the triangular block cut system or center V-cut and slabs.

Whether the heading is driven at the bottom leaving roof to be shot down (Figure 147), or at the top leaving a bench to be taken up (Figure 148), depends on one or more local conditions. Shooting the roof down, or back stoping, as this

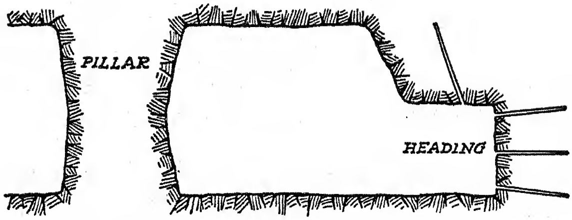
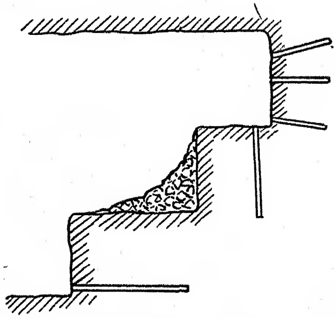


Fig. 147—Bottom heading and back stope method

Fig. 148—Top heading and bench method



method is called in the metal mines, is an excellent practice where spalls should be eliminated, as in producing limestone for kilns. This method is especially effective if it is possible to take advantage of a parting as large quantities of stone can be brought down with a very low explosive consumption and, if the proper secondary blasting methods are followed, a minimum of spalls produced.

The heading may be advanced by either the V-cut or the saw-tooth method, Figure 149 and Figure 150.

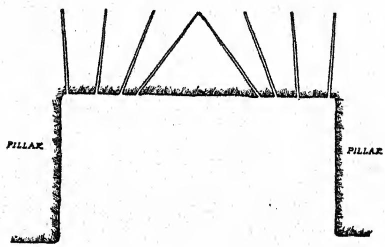
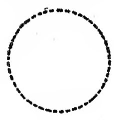


Fig. 149—Advancing heading with V-cut and slabbing rounds

When the bench method is used it is essential to clear the bench with the shot in order to save expensive hand labor and double handling of rock. This can usually be done by the use of the proper kind and grade of explosive and of electric



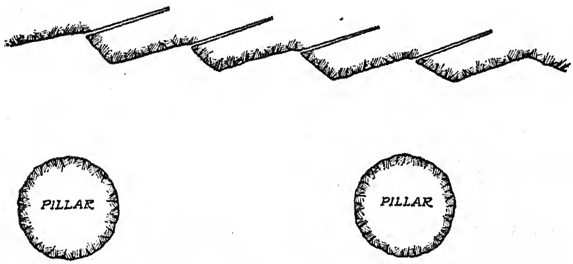


Fig. 150—Saw-tooth method of advancing heading leaving circular pillars; an economical method but prone to scatter the material

firing. From the standpoint of labor costs it is important that the benches be shot hard enough to clean them and yet pile the material up properly for the particular type of loading used, whether hand or mechanical.

Sometimes the heading is driven in the middle of the seam and a combination of bench, or underhand stope, and back stope method is used, as in Figure 151. This system is especially adapted for a seam where there are natural partings to be taken advantage of in driving the heading, as a good parting at both top and bottom will reduce the cost of blasting. This combination of bench and back stope gives best results where the

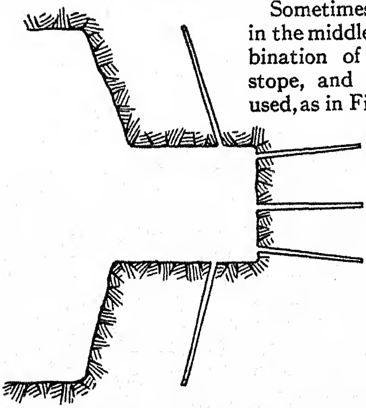


Fig. 151—Combination of bench and back stope method suitable for faces 25 ft or more in height

face is from 25 to 30 ft high. With higher faces, unless the bench is kept vertical, too much material from back stoping will pile up on the benches.

Sectional steel has been used with some success in drilling benches from 12 to 24 ft high so that the entire bench can be shot at one time. The heading is first cut 8 to 12 ft high, then sectional steel holes can be drilled to the bottom of the bench. This is of particular advantage where a mechanical shovel is used as a full shift's run of material can be shot down at once.

The rooms may be advanced as large tunnels, leaving rectangular pillars for support and running crosscuts from the main tunnel as in coal mines, or circular pillars may be left for support at various distances dependent on local conditions. The size of pillar left is governed by the height and width of the room and by the condition of the roof and cap rock overlying the deposit.

When circular pillars are left there is a greater width of face most of the time than with rectangular pillars and, therefore, the saw-tooth face is used to best advantage. This method of working the face is more economical because each hole always has two free faces to break to and furthermore if one hole misfires or fails to break its full burden, it is not nearly so serious as when dependent shots fail to break.

In working the full face with the triangular block cut system, both rooms and entries are advanced by blasting successive V-cuts, each of which breaks down a roughly triangular block of stone (Figure 152).

The holes for each V are fired simultaneously with electric blasting caps. After the first or tight V is taken out, two cuts can be blasted at once in each room or entry. The success of this method of blasting depends greatly on the care exercised in drilling. Drill holes should be placed so that each "set" or "line" of holes is at right angles to the other set in the same triangular block cut and depths should be determined so that all holes reach as nearly as possible the apex of the wedge thus formed. If the holes form an obtuse angle, the round obviously will not produce as much tonnage per foot of borehole as if they form a right angle. On the other hand, drill holes placed so as to form an acute angle not only reduce the tonnage included in the block, but also cause a tight blast which will probably fail to break to the bottom of the holes, leaving a ragged face at the back of the angle and causing excessive and undesirable shattering of the stone.

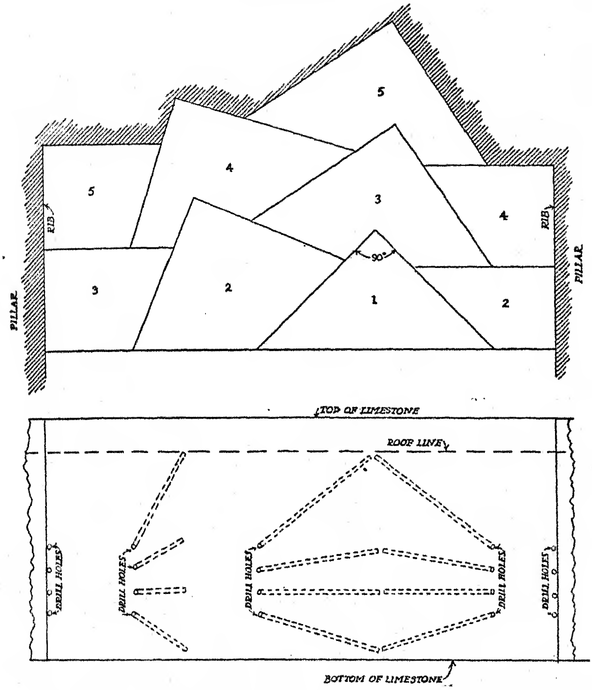


Fig. 152—Advancing room by triangular block cut method

Many drill operators make use of large size T squares or triangles, or oftentimes empty dynamite cases, to aid them in lining up their drill steel at the correct angle when starting boreholes. Hammer type drills mounted on tripods or columns have been employed for this work for many years but recently in operations where the stone is loaded out after each shot, wagon drills have been used with considerable saving. Wet drilling is sometimes used to reduce the dust hazard.

The chief advantage of this system of blasting lies in the large volume of blasted stone that can be accumulated in a single room, the thickness of the seam being the principal factor controlling the quantity of stone that can be blasted down through one or more complete cycles of shots. Rooms can be advanced from 20 to 30 ft and filled with from 1000

to 3000 tons of stone. Where mechanical shovels are used for loading, this offers a decided advantage as it is always desirable to avoid frequent moving of the shovels and rearrangement of loading tracks.

A systematic method of calculating the explosive charge will result in economy. The burden on each cut can be calculated by the following formula, $\frac{D_1 \times D_2 \times H}{24} =$ Volume in tons, in which D_1 and D_2 = Depth of the breast holes on each side of the angle, and H = Height of stone (Figure 153).

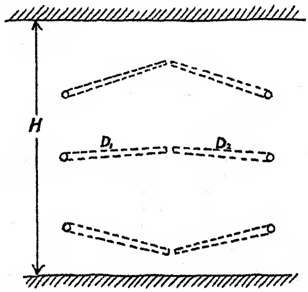


Fig. 153—Typical six hole cut

Taking a hypothetical case where the depth of the breast holes are 10 and 12 ft respectively and the height of the limestone is 15 ft, the calculation will be as follows:

$$\frac{10 \times 12 \times 15}{24} = 75 \text{ tons}$$

Now assuming that in practice an explosive factor of 0.8 of a pound of dynamite per ton of limestone is required, and multiplying this by 75, it is found that 60 pounds of dynamite is the theoretical charge needed to displace this triangular block. Of course, irregularities in the face of the stone necessarily make the calculation of tonnage by this method an approximate figure so that the blaster must vary the charge from the theoretical and distribute it among the boreholes according to conditions, but he is in much better position to judge the charge accurately on the basis of such a calculation than from merely looking at the block of stone. It will save time if blasters are furnished with tables of loads based on different depths of breast holes so that they will not have to calculate each angle.

When used with a wagon drill this method is adapted to faces as high as 30 ft where the material is loaded out after each shot and where fines are no objection. Loading equipment should be as mobile as possible, caterpillar shovels and trucks being most suitable.

It is impossible to recommend any one kind or grade of dynamite for underground blasting of limestone that would

suit all conditions. A great deal depends on the character of the stone, whether holes are wet or dry, the method of loading the stone, the fragmentation desired, and the ventilation. In operations producing flux stone and where fines are undesirable, low velocity Du Pont "Extras" C-1 or D-1 and "Red Cross" Blasting No. 5 F. R. usually give best results if the holes are dry and the shooting fairly easy. Fumes may be improved by packing in special wrappers. In harder stone, where partings are tighter or where greater fragmentation is desired, high velocity "Extras" or "Gelex" No. 1 or No. 2 are suitable, the latter, of course, furnishing in addition sufficient water resistance for most operations. Occasionally it is still necessary to use Du Pont Special Gelatin 40% or 50% for very hard shooting stone or severe water conditions. Usually the lower velocity explosives are best for throwing the stone back from the face although in exceptional cases gelatin gives better results.

CLAY

Siliceous Fire Clay. This type is also commonly known as flint clay and its characteristics such as hardness, thickness of seam, occurrence, etc., vary greatly even within the limits of a small area. The formation is normally overlaid with coal or sandstone and the latter material usually forms the floor. It may consist of interbedded hard and soft layers, in which case the latter can be drilled with a hand auger, but if the hard seams require drilling an air hammer must be used.

The mining practice follows the usual room and pillar system. Entries are driven only wide enough for transportation and the rooms as wide as conditions will permit without timbering, usually 10 to 15 ft. Pillars are wide enough for ample support, generally 30 to 50 ft.

The overlying coal is sometimes mined off first, particularly if it is of good quality or if it is difficult to keep up. In any event, care is taken not to mix the coal and clay. Flat slab holes will then serve to lift the clay and provide fairly economical mining costs.

If the coal is not mined off first it is necessary to open up the face with some type of breaking-in shot usually placed to take advantage of soft seams or slips. Electric firing is gradually replacing the cap and fuse method due to increased safety and permits an opening shot of two or more holes, additional holes being drilled and fired as required or shot in a complete round using delays. Holes are usually drilled 3 to 6 ft deep and carry a burden of 3 to 4 ft.

The economical shooting of flint clay requires much care in preventing excessive fines which reduce the output of the mine.

The most suitable explosives are 30% to 40% "Red Cross" Extra, Du Pont "Extra" C or D, "Gelex" No. 2, or 30% Special Gelatin.

Plastic Clay. These clays usually occur with a considerable degree of uniformity extending throughout a segregated district making possible a certain standardization of general mining methods and shooting practices.

The clay seams vary from 6 to 12 ft in thickness, are usually overlaid with a thin layer of low grade coal and underlaid with sandstone and are developed on the typical room and pillar system. Width of rooms usually varies from 10 to 15 ft, depending on roof conditions with pillars wide enough to prevent settlement, generally 40 to 75 ft. After development has progressed to the property limits, the major part of the pillars can be recovered in the "drawing back" or retreating process.

The low silica clays are usually fairly soft in the upper portion increasing in hardness toward the bottom. With a smooth parting at the roof coal, the so-called "mining" or "cut" holes are located in the upper part of the face with "lifter" holes and "bottoms" to pull the center and lower portions in rotation. Figure 154 shows the arrangement of holes for a typical round in medium hard clay. Holes are bored either by hand or with a power auger and are usually 2¼ in. in diameter and 5 to 8 ft deep. Three "mining" holes are generally required to pull the top with two or three "lifters" and two or three "bottoms," depending upon conditions.

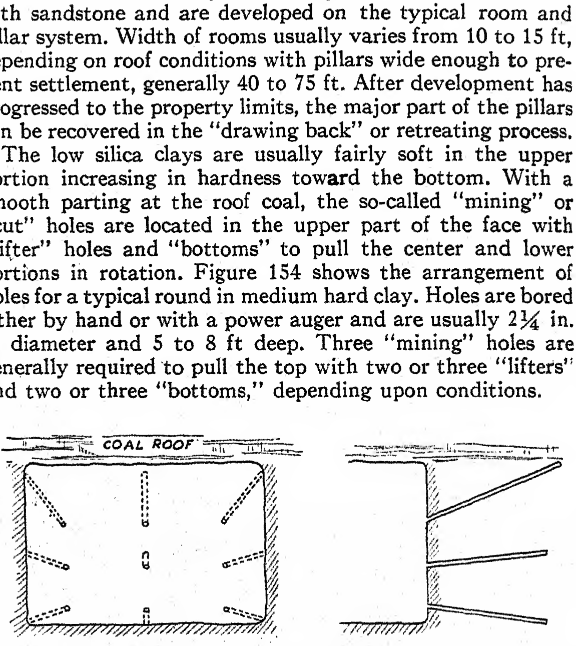


Fig. 154—Typical round in medium hard clay

Explosives commonly used are No. 1, No. 4, or No. 5 Pellet Powder in the top holes and sometimes in the "lifters," "Gelex" No. 2 or Du Pont "Extra" C or D in the "lifters" and

"bottoms"—depending upon the hardness and water conditions. The more highly siliceous clays are usually harder, requiring dynamite for the entire round.

Shots are commonly fired with a wax finish fuse due to the generally damp conditions prevalent in clay mines.

A production of 2 to 2¼ tons of clay per pound of explosive is obtained under average conditions. A fair degree of fragmentation without excessive throw is desired to facilitate handling and there is no loss due to the presence of fine material.

GYPSUM

Gypsum occurs principally in flat, relatively continuous beds similar to coal, but is also mined in pitching and branching veins similar to ore deposits. The mining methods vary, of course, with the nature of the deposit. The room and pillar system is commonly used for the flat beds and drift and stope methods for the pitching veins.

Gypsum is a relatively soft material—it can be drilled with electric augers, and is rather easy to shoot, although there is an element of toughness in its consistency. Some gypsum deposits are split by thin seams of anhydrite ("fire rock"), which is considerably harder and makes drilling somewhat more difficult.

Blasting Off the Solid. The flat deposits of gypsum are normally shot off the solid, although in some of the thinner veins, loading by shaker conveyors has led to undercutting.

A typical series of holes for blasting off the solid is shown in Figure 155. This illustrates a 14-hole round in an average 22 ft wide face in gypsum 36 to 42 in. high. Holes are usually drilled 6 to 8 ft deep. The face is advanced by a 10-hole fan-shaped round which leaves about a 5 ft slab to be shot off with the following advance round. As the face advances, the direction of drilling is varied to take advantage of the best chances and the slab may shift from one side to the other as conditions warrant.

The success of the fan-shaped round is very much influenced by proper drilling. The opening holes should not be permitted to become entirely dependent. The proper layout is shown in Figure 156-A in which the No. 2 hole finishes so that it can break clean, even if No. 1 leaves a foot or two unbroken. Figure 156-B illustrates improper drilling since hole No. 2 is too deep and entirely dependent upon No. 1.

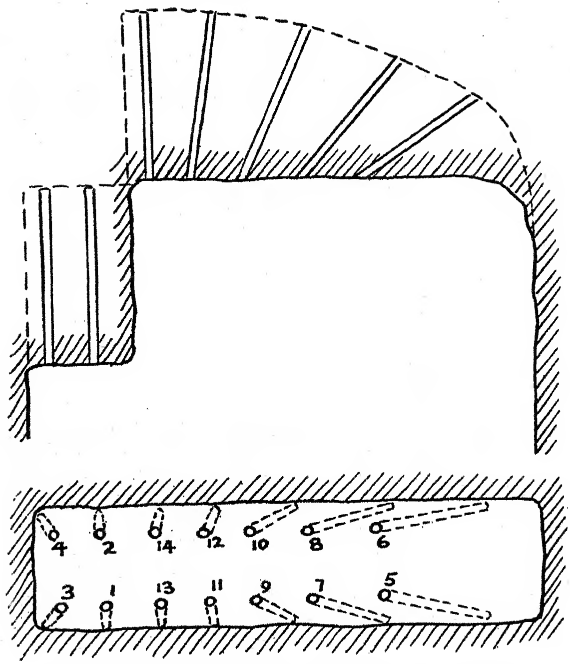


Fig. 155—Typical round for blasting gypsum off the solid

In addition to its influence on depth of advance and production per round, proper drilling has an important bearing on loadability. The bottom partings on most of the thinner beds of gypsum are poor due to irregularities such as rolls and boulders in the underlying rock. These protuberances are hard limestone that cannot be drilled with gypsum drilling equip-

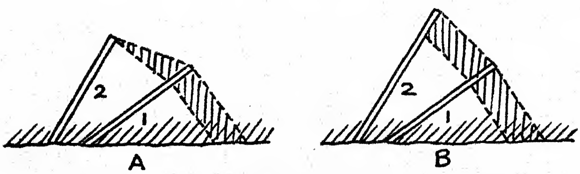


Fig. 156—Proper (A) and improper (B) methods of drilling opening holes

ment. Nevertheless, the bottom holes must be drilled to within an inch or two of the bottom parting even if it is necessary to relocate and redrill some holes when obstructions are encountered. If a roll or boulder is present and a bottom hole in the vicinity does not go down to the parting, some gypsum will be left on the bottom. Succeeding holes will also fail to clean bottom and loading will be seriously hindered since all such material not freed by the blast must be wedged loose.

Bottom holes are always loaded heavier and shot first because they spread and clean better when they have the heavier burden. Furthermore, it is not desirable to load heavily in top holes, since the roof may be weak or tender. Roof partings are usually smooth and top holes bottoming within 3 in. of the parting will clean well.

Bottom holes are loaded with 10 to 12, 1⅛"x 8" cartridges of Du Pont "Extra" F-1, Gypsum A, or the equivalent. Top holes require about half the above charge. A normal yield is about one ton of gypsum per pound of dynamite.

Rotation firing with ordinary blasting caps and trimmed safety fuse is customary.

In addition to the fan-shaped advance round, some gypsum, especially in thicker beds, is blasted with a vertical V-cut round and side slabs. Under such conditions electrical firing gives the best results. The V-cuts are broad and deep and will break well if the cut holes are shot together with instantaneous electric blasting caps. The relief and slabbing holes are, of course, fired with delay electric blasting caps.

Blasting Undercut Gypsum. Recently, mechanical loading with shaker conveyors has been introduced into a few operations in the thinner gypsum beds. The feasibility of this type of loading has been largely due to the successful adaption of machine undercutting to the unusual conditions involved. Chain type cutting machines similar to those used in coal are employed and the depth of cut is normally about 8 ft. Because of the hard and irregular bottom underlying the gypsum, however, it has been necessary to place the cut about 10 in. above the bottom. This leaves a thin bench of gypsum beneath the cut which is hard to drill and shoot in such a way that the floor is cleaned off. Because of this, undercutting for the full width of the face has proved impractical in many instances.

In a typical 25-ft wide face, the best results are obtained by undercutting the middle 15 ft leaving 5-ft slabs on each side to shoot off the solid. This method reduces the number of

flat holes in thin burdens beneath the cut, it cleans the bottom better, especially near the ribs, and by throwing the gypsum more toward the center improves loadability and lessens damage to timbering. The drilling layout for a typical adaptation of undercutting is shown in Figure 157.

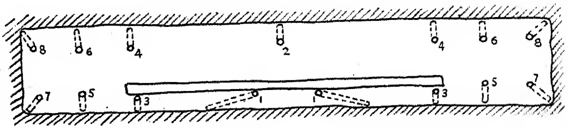


Fig. 157—Typical round for undercut gypsum

It is quite essential, as is the case in shooting coal, that the kerf be thoroughly cleaned of cuttings before any holes are shot.

SALT

Salt commonly occurs in flat seams from 8 to 40 ft thick or in huge underground domes several hundred feet in thickness. Regardless of the size of the deposit, nearly all salt is undercut either by undercutting machines or by driving rather wide headings 8 or 10 ft high. In seams of medium thickness, salt may also be sheared in addition to the undercut.

The room and pillar method of mining is nearly always used in one form or another. As in the case of limestone, the heading may be driven at either the top or the bottom of the seam in which case the bottom or roof will be shot down by benching or stoping methods. In the case of dome salt deposits, the body is entered through a shaft and the work may be carried on at several levels simultaneously. An 8- or 10-ft heading which may or may not be undercut is advanced a considerable distance, after which the roof salt is blasted down by overhand stoping methods, usually called "inverted benching" in the salt mines. Rooms of this type may reach an eventual height of 60 to 80 ft.

Salt is drilled with electric augers and the rounds are typical of blasting to undercut burdens. Boreholes are drilled across the face in several horizontal lines. To minimize drill set-ups on wide faces, the holes are usually fanned out from a few set-ups, but they are so directed that they are equally spaced at the back of the cut. The plane of the lines of holes is usually parallel to the undercut, although the bottom line may be

pitched downward slightly. The bottom row of holes is naturally fired first, and if the holes have a downward pitch, the bottom burden is thrown out from the face somewhat better. This gives the upper benches more drop and roll when they are shot and improves loadability.

The holes are spaced to give a burden of about 5 tons on each and the loading factor is usually about 2 tons per pound of dynamite. Dynamites of the Du Pont "Extra" F-1 type are most commonly used. In seams 8 to 10 ft thick, 3 rows of holes are required. Electrical firing with instantaneous electric blasting caps is commonly used and each row is shot separately starting, of course, with the bottom row and working upward. In over-hand stoping, the undercutting drift may be shot electrically as just described, but the stoping shots are frequently set off with cap and fuse.

Where the salt is not undercut, it is shot off the solid with V-cut rounds in the center of the face widening out to the ribs with side slabbing rounds.

TALC

Talc deposits are usually mined by drift and stope methods. Drifts are largely exploratory, usually driven about 7 x 8 ft, employing 6-hole V-cuts or 4-hole diamond cuts. The average round consists of about 26 holes. There is considerable variation in the nature of talc and some of the more fibrous varieties are difficult to blast. Hence, development rounds are not deep, 4½ ft being considered a satisfactory advance.

Raises are driven for stope development and for ventilation. They are somewhat smaller in section than drifts and are commonly shot with 18-hole rounds using the 4-hole diamond cut.

Stope blasting employs the common types of slabbing rounds with holes 8 to 10 ft deep.

Most talc could be shot with low strength ammonia dynamites but the majority of this work is wet so that "Gelex" No. 2 and Special Gelatin 30% are usually preferred. These grades are also desirable because of their excellent fume properties and because they are plastic and cohesive and load well in uppers.

Normal drift rounds require about 40 lb of "Gelex" No. 2 or 50 lb of Special Gelatin 30%. Raise blasting requires somewhat less powder, usually 30 to 40 lb per round.

The rounds are usually fired with ordinary blasting caps and safety fuse trimmed for rotation firing.

CHAPTER XIV

BLASTING IN QUARRIES

Quarrying may be roughly divided into two kinds, depending on whether the material blasted is to be used for dimension stone, or whether it is to be used for road building, fluxing stone, cement, concrete aggregate, or other uses. In the former case, the stone must not be shattered, so it should be moved out in as large pieces as possible. Methods for accomplishing this will be discussed later in this chapter.

For most other uses, the stone should be well broken up. This is accomplished by the use of high explosives in some one of the four general methods of carrying on quarrying operations: (1) well drilling, (2) tunneling, (3) benching, or (4) snakeholing. The method followed will depend upon the nature of the rock, the size of the deposit, the use to which the broken material will be put, and the equipment available for drilling, digging, transportation, and crushing.

Regardless of the method used, the blaster must know the height of the face and, in the case of a sloping bank, the amount of toe, or in other words, the distance that the bottom of the bank extends out beyond the crest. Without these two distances, he will be seriously handicapped in determining the burden and the proper charge for a successful blast. The following is a quick and simple method of determining the height and toe with a practical degree of accuracy. It is based on the fact that the altitude and base of a 45° right triangle are equal.

Determining Height and Toe of a Quarry Face. Construct a 45° right triangle of 2-in. square material with the sides of the right angle 24 in. long. These dimensions are suggested to give a triangle which will be of a convenient size and yet substantial. Set this triangle on the edge at the top of the quarry with the vertex A as shown in Figure 158. It is suggested that a level be used to keep the base horizontal. Site along the slanting edge of the triangle to a point B on the quarry floor which can be located with the assistance of another man. Measure the distance AB with a tape.

This line AB is the hypotenuse of a 45° right triangle, one leg of which is AC, the height of the quarry face, and the other, BC, the base of the triangle. These two distances are the same and may be found by multiplying the distance AB by 0.71, the sine of 45°. The neces-

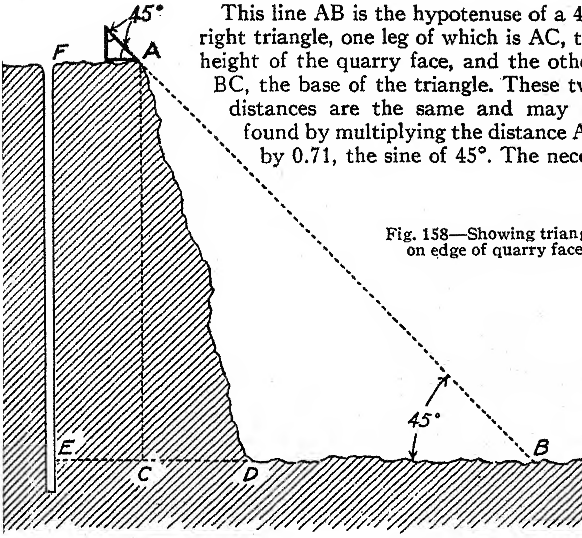


Fig. 158—Showing triangle on edge of quarry face

sity for making this calculation can be avoided, however, by the use of Table XXV in Appendix I at the end of this book, from which the distances AC and BC can be determined at once, as soon as the distance AB is known. Then the distance BD from the point in the quarry floor to the bottom of the face can be measured easily, and when this is subtracted from the distance BC determined as above, the distance that the toe extends beyond the crest of the face will be found.

As an example, suppose that the distance AB is found to be 100 ft and the distance BD 55 ft. The distance AC or BC is found by the table or by calculation to be 71 ft. The distance CD or the toe will be 71 − 55 or 16 ft. Therefore, this particular quarry face will have a height of 71 ft and a toe of 16 ft and if well drill holes were placed 10 ft back of the crest at F, Figure 158, the burden at the toe would be ED or 10 + 16 = 26 ft.

This method of calculation works very satisfactorily for quarry faces up to or slightly over 100 ft, but is difficult of application for greater heights as it is impractical to use a tape much more than 150 ft long. It is recommended that a transit be used to determine these values on very high faces

It is also possible to use this 45° triangle to locate the holes to be drilled for a new blast. For instance, it is desired to locate a line of holes 15 ft apart so that each hole will have a burden of 20 ft at the toe and to drill each hole 3 ft below grade in a quarry where the line AB measures 98 ft and the distance BD 60 ft. The table shows that AC and BC are 69 ft, so the toe extends 69 − 60 or 9 ft beyond the crest of the face. Hence to give a burden of 20 ft in front of the hole, it is merely necessary to measure 20 − 9 or 11 ft back from the edge of the face to find the proper place to drill. As each hole is to be extended 3 ft below grade, the depth in this case will be 69 + 3 or 72 ft. Repeating this simple procedure at 15-ft intervals will insure that each hole is drilled to exactly the proper depth and carries the proper burden. This method is particularly valuable in quarries where the top of the face is irregular.

WELL DRILLING

This method is commonly used for quarrying limestone, cement rock, shale, sandstone, trap rock, and granite. It consists essentially of blasting a relatively vertical free face with large diameter vertical well drill holes uniformly spaced along one or more lines located in back of and parallel to the face. It is readily applicable to quarry faces 30 to 100 ft high and is frequently employed in straight-breaking, easy-drilling banks up to 200 ft in height.

Height of Face. There has been and still is considerable difference of opinion as to the most economical or efficient height of face to work with power shovels. Some think the higher faces best because moving of shovels and tracks is less frequent. Of course, much depends on the size of the shovel in use and the kind of quarry. Many stone quarries are side hill operations in which the height of face is governed by the topography of the ground. Often these faces may run from 100 to 250 ft in height. There are very few quarries which could afford to operate two or more separate well drill benches. Therefore, in most cases, it is necessary to accept conditions as they are, especially if the quarry has been opened and worked for some time. However, in certain sections of the country, especially in the midwestern states, most of the quarries are pits. The country is flat and any height of face can be obtained by sinking to any desired depth below the level of the surrounding country. The usual custom in this

section is to carry the face not more than 40 ft in height and this seems to be the most economical for shovels up to 110-ton weight. The introduction of crawler shovels has tended to make lower faces easier and more economical to operate than higher ones.

If there is a well-defined parting at a reasonable depth in the deposit, the quarry floor should be carried at that level as the stone will be much more easily broken off at that point.

Diameter of Holes. The diameter of the holes will vary from 4 to 9 in. depending on the hardness of the rock and the height of the bank. 4- to 4½-in. holes are often used in the softer rock with faces less than 40 ft high, while the more common 6-in. hole gives better results in harder rock in higher faces. The 9-in. hole has proved economical in high faces in trap rock, granite, quartzite, and other hard diabase rocks where drilling is very slow and expensive, as it has allowed the operator to take considerably more burden per hole.

Spacing of Holes. The burden on a line of holes or the distance back of the face and the spacing or distance apart will depend upon the height of face, the hardness of material and the diameter of the holes. The general average for 4- to 6-in. holes is about as follows:

Holes 30 to 40 ft deep, burden 15 ft, and spacing 12 ft.

Holes 40 to 50 ft deep, burden 18 ft, and spacing 14 ft.

Holes 50 to 90 ft deep, burden 20 ft, and spacing 16 to 18 ft.

Holes over 90 ft deep, burden 25 ft, and spacing 20 ft.

In recent years there has been a tendency in limestone quarries with banks 30 to 50 ft high to widen the spacing and take a lighter burden, but maintaining at least the same shearing area per hole. It is by no means unusual now for these quarries to have burdens appreciably less than the spacing. This type of drilling pattern is also quite common in granite.

Theoretically both the spacing and burden should be increased by one-half when changing from 6-in. to 9-in. holes, but this is seldom possible, particularly if it is desired to get as good fragmentation at the same explosive cost per ton. In most formations, it is definitely a mistake to attempt to increase the burden and spacing by more than the above ratio as this requires each hole to shear too much area and the

charge of explosives is so far from the center of the block, that fragmentation is bound to be unsatisfactory.

In relatively shallow faces from 25 to 40 ft in height, two or more rows are often shot at one time to gain sufficient volume of material to minimize shovel and track movements. This method is often advantageous with shovels with long booms and wide digging radius. This system will give best results if there is a free cleavage plane at the bottom of the face and fragmentation will be improved if the holes are staggered. If the bottom is hard to pull, there may be some question of the economy of multiple row shooting, as in this case, it will be necessary to decrease the burden progressively as the rows recede from the face, thus increasing the drilling cost per ton. Furthermore, in soft rock, which has a tendency to break in back of the holes, there may be a definite disadvantage to shooting multiple rows, as the back break will be obtained only from the last row of holes. The firing of two or more rows together is not recommended where the face exceeds 50 ft in height.

Depth of Holes. Well drill holes should normally be drilled to a definite depth below the quarry floor, this depth depending upon the height of the face and the hardness of the rock. In cases where there is a good parting of the quarry floor, they need not be drilled below this level, but they should be drilled to the full depth of the face. The question of the depth of the holes is of utmost importance, and it should not be left to guesswork by the driller. A system of levels should be run around the quarry with an engineer's instrument and bench marks established on each bench to indicate the exact elevation with reference to the quarry or loading floor. These bench marks can be used as permanent reference points for the placing of stakes at regular intervals around the quarry and far enough back to prevent disturbance by blasts. Each stake should be marked with the grade level with respect to the quarry floor or in some other manner to indicate to the driller the exact location of the floor with respect to the top and the driller should be instructed to refer to these stakes when drilling holes. This method of assisting and checking the drill crew has often solved very serious trouble arising from short holes and consequent failure to pull the bottoms.

The following table gives the recommended depth of subdrilling in faces up to 200 ft high where there is no natural parting at the quarry floor:

HEIGHT OF FACE	SUB-DRILLING
30 to 40 ft	3 ft
40 to 60 ft	4 ft
60 to 90 ft	5 ft
90 to 125 ft	6 ft
125 to 150 ft	7 ft
150 to 175 ft	8 ft
175 to 200 ft	10 ft

It is often the case that the face cannot be kept vertical and there is an extra heavy burden on the bottoms of the holes due to an out-sloping toe. In this type of work it is sometimes necessary to spring the bottoms of the holes in order to concentrate enough explosive at the point where the burden is heaviest. Another way is to drill a number of snakeholes into the heaviest portion of the toe and fire them at the same time with the well drill holes, thus relieving the burden at this point.

Buffers. Sometimes part of the material from a previous blast is left against a face of rock to be shot down. This broken rock is called a "buffer" or "blanket" and this method is often referred to as "buffer blasting" or "carrying a buffer." The idea of a buffer is that it offers a greater resistance and tends to confine the force of the explosion so that better fragmentation is gained without throwing the rock too far out. When the floor area between the track and the face is limited, a buffer is essential. For moderately low faces a buffer is often advantageous even if there is plenty of room. Sometimes, however, too heavy a buffer is used and the stone does not come out far enough to permit easy access for the secondary preparation of the stone. This means frequent and costly delays for the shovel while the large stones, not found until uncovered by the shovel, are drilled and blasted. If the stone lies in thick, heavy ledges with open seams and has a tendency to slide out in large blocks before the explosive has had time to shatter them, it is better to use little or no buffer and allow the stone to be thrown out farther so it can be easily redrilled and prepared sufficiently ahead of the shovel. In higher faces, say from 60 ft up, no buffer whatever is needed. Each blast is cleaned up before another is thrown down.

Loading and Firing. Methods of loading, tamping, and firing well drill blasts are described in Chapters IX and X.

Explosives. In loading well drill shots, it is usually unnecessary to consider the fume characteristics of the explosive and as a rule it is desirable to choose cartridges that are about ½ in. smaller in diameter than the holes in order to get good loading density and to speed up the loading operation. As the greatest burden is normally at the toe, it is customary to load the strongest and heaviest grades in the bottom and use the lower strength, more bulky dynamites in the top, frequently in the form of decks. The blaster must consider the type of rock, the burden, the amount of water present and the desired fragmentation in choosing the type of explosives to use.

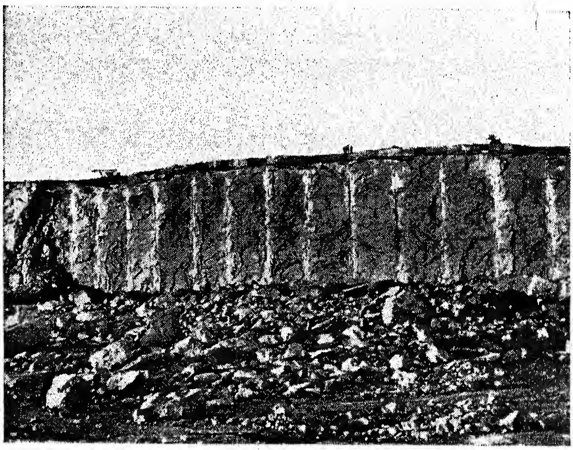


Fig. 159—Granite quarry with face 110 to 140 ft high in which "Nitramon" is regularly used in well drill holes

The easier breaking rocks such as shale, clay, and soft lime or sandstone may be satisfactorily shot with the "Red Cross" Blasting Free Running grades if the work is reasonably dry. Otherwise "Red Cross Extra" 20% to 40%, or "Gelex" No. 2 should be used. "Nitramon" No. 2 has also been quite satisfactory in some formations where the face is at least 40 ft high. Limestone, depending on the type, can be shot with "Nitramon" A, B, or C, or "Red Cross Extra," or Du Pont Special Gelatin 40%, 50%, or 60%. The Du Pont "Extras or "Gelexes" may be used for top loads. The harder rocks

like trap or granite will often require "Nitramon" A or 75% Special Gelatin for a bottom load, then "Nitramon" B or 50% to 60% Special Gelatin with "Nitramon" C, "Nitramon" No. 2, "Gelex" No. 2, or the lower strength "Red Cross Extras" or Du Pont "Extras" for top loading.

The loading factor will vary greatly with the rock, but 4 to 6 tons per pound is a fair average for limestone and 2 to 3 tons per pound for trap rock.

TUNNELING OR COYOTE HOLING

This method of quarrying consists of driving small tunnels about 3 by 4 ft in cross section horizontally into the face at the floor level. Side tunnels or wings are turned off the main tunnel at right angles and the explosive charge is loaded in these. The tunnels are drilled and blasted by the methods used for small drifts in ore mines, described in Chapter XII.

The principle involved is to kick out the toe, thus undermining the top, which, being severely shaken and lifted by the blast, will fall of its own weight.

Tunneling or coyote holing is particularly adapted to high faces in hard slow-drilling rocks such as columnar trap and quartzite where it is usually more economical to drive the tunnels than to attempt to use well drills. It is not recommended for faces less than 60 ft high and preferably the height should exceed 80 ft. It should not be used in deposits having a horizontal stratification such as most limestone and many granites, as there is a great possibility of the toe being pushed out so easily that the top will be insufficiently broken or even left standing. Columnar trap rock, quartzite that shows no particular stratification, and deposits having vertical stratification are suitable for this system of blasting. It should be realized that with this method of loading only a small part of the rock involved in the blast is in direct contact with the explosive. If the material to be blasted tends to break in large boulders like some non-columnar trap rocks, a different method will probably give more satisfactory results, particularly if good fragmentation is desired.

The main tunnel should usually be driven at right angles to the face and to a depth of about 50 ft if it is planned to have only one set of wings, or to 70 or 75 ft if it is planned to use two sets of wings. The wings should ordinarily be turned off the main tunnel at an angle of 90° in either direction and

they should seldom be more than 75 or 80 ft long. These distances are about the limit for convenience and economy in mucking and loading.

The cost of driving these tunnels will, of course, vary greatly depending upon the locality, the material encountered, the method used, and the cost of labor and materials, but it is believed that $5.00 to $7.00 per foot is a fairly average cost for drilling, shooting, and mucking a 3 by 4-ft tunnel in hard trap rock. Relatively large quantities of explosive are loaded in the wings and it is, therefore, imperative that they be located accurately, as it might be disastrous to fire a tunnel blast in which one of the wings had been allowed to approach say within 15 or 20 ft of the quarry face. The entire proposed lay-out of the tunnel and wings should be drawn up by an engineer showing accurately the contour of the face with respect to the tunnel and the wings should be checked frequently during construction by an engineer to make certain that they are going in the desired direction.

In trap rock over 150 ft high, it is advisable to use a combination of tunneling and well drill methods, placing the well drill holes directly over or slightly behind the back wings of the tunnel and stopping them some distance above the tunnel level. If the well drill holes are fired at the same time as the main tunnel, excessive back break can often be prevented and the face left in a safer condition.

Methods of loading, tamping, and firing tunnel shots are described in previous chapters.

The quantity of explosives needed for any particular tunnel shot should be calculated on the "neat square" of the shot, that is, the product of the length of the main adit, the length of the wing, and the average height of the face from the top to the wings. The loading factors will average about 3 to 5 tons per pound, but the yield of stone will often run at least 25% higher than this due to the back and end break from the shot.

Formerly black blasting powder was used extensively in tunnel blasts, but it has been replaced largely by "Red Cross" Blasting Free Running types which eliminate the spark hazard. In very hard rocks, 40% "Red Cross Extra" and even 60% Special Gelatin have been used. More recently, "Nitramon," usually the C grade, has been substituted for dynamite, improving the safety of the operation and adding to the comfort of the workmen by eliminating the dynamite headache.

BENCHING

In this method, the face of the quarry is carried forward in a series of benches corresponding somewhat to stair steps on a large scale. The stairs are not always regular, but vary with the thickness of the strata or ledges, the location of advantageous seams, and the drilling equipment. Holes are drilled vertically in either a single row or in two or more rows. In the case of multiple rows, fragmentation will be improved by staggering the holes.

In low faces up to 10 or 12 ft in height, hammer drills are generally used. The holes, which bottom about 1½ in. in diameter, are usually spaced from 4 to 5 ft back from the face and the same distance apart. In higher faces, from 12 to 30 ft, the high-speed wagon drills are used, giving holes which will bottom at least 2 in. in diameter. Here the holes may be spaced up to 10 ft apart in each direction. If the benches are much higher than 30 ft, it will be advisable to use well drills for drilling. In some types of rock, a square drilling pattern such as 8-ft burden and 8-ft spacing will tend to move the entire burden out in a more or less unbroken block. This can usually be corrected by reducing the burden and increasing the spacing, for example, drilling the rows 7 ft back of the face with the holes 10 ft apart. The benching method of quarrying usually gives excellent fragmentation due to the generally uniform distribution of explosive throughout the blast.

The holes should be loaded at least one-half full of explosive, well tamped all the way to the collar, and fired simultaneously with electric blasting caps. The type and grade of explosive depend upon the character of the material to be blasted and the degree of fragmentation desired. Where the rock is not very hard, such as medium limestone, and a minimum of spalls or fine material is desired, "Red Cross Extra" 25% or 30% or the equivalent grade of low velocity Du Pont "Extra" may be used. Where the rock is somewhat harder and greater shattering is desired, "Red Cross Extra" 40% or 50% or an equivalent Du Pont "Extra" will do the work. In very hard rock or where the water conditions are severe, "Gelex" No. 1 or No. 2 or 40% or 50% Special Gelatin may be required.

The introduction of high-speed wagon drills and mobile crawler shovels have made the benching method both efficient and economical for low faces. The same explosive loading factor should be used as for loading well drill holes, but the

explosive will rise higher in the holes with consequent better distribution and fragmentation.

SNAKEHOLING

This method of working a quarry face has largely been replaced by the well drill method. It may be employed for faces up to 60 ft in height in hard, massive, irregular formations having no particular lines of cleavage or in cases where the strata are on edge in such a manner as to prevent easy drilling of down holes. In the latter case, the holes should be drilled perpendicular to the stratification if possible. The method consists in drilling a single row of holes almost horizontally into the base of the face and then springing them sufficiently to accommodate the required amount of explosive. Tripod drills are usually used and the holes should be started 3 or 4 ft above the quarry floor, dipping just enough to bring the toe of the hole down to the floor level. The holes should normally be drilled to a depth equal to one-half the height of the face and spaced from 8 to 10 ft apart. Full information concerning springing holes and the precautions that must be observed are found in Chapter VII.

The holes, which have been sprung, must be allowed to cool before loading. The charge per hole, depending on the burden, may run from 150 to 500 lb, and it is recommended that the whole charge be loaded in the sprung portion of the hole, thus leaving the entire shank of the hole for tamping. It is quite essential that snakeholes be tightly tamped all the way to the collar. In medium rock, 40% "Red Cross Extra" or Special Gelatin is recommended for springing, with "Red Cross" Blasting Free Running grades, "Red Cross Extra" 40%, or the equivalent Du Pont "Extras" for the main loads. In harder rock and where more shattering is desired, a 50% grade may be required for springing and 40% Special Gelatin for loading. Extremely hard rocks of the granite and trap rock type will sometimes require the use of 60% Special Gelatin. The holes should always be fired simultaneously by electric blasting caps. The loading factor will be about the same as that used for well drill holes in the same formation.

DIMENSION STONE

High explosives are almost never used for quarrying dimension stone as they are likely to start invisible cracks and seams which will eventually ruin what is apparently a perfectly sound

block of stone. "A" Blasting Powder of a rather fine granulation is used in this work, although "B" Blasting Powder and Pellet Powders are also used to some extent. Hammer drill holes 1½ in. to 2 in. in diameter are usually drilled very close together along the desired breaking line. These holes are loaded with very small charges of blasting powder and tamped so as to leave a rather large air cushion. All holes should be fired simultaneously with electric squibs. The purpose is to move a block of stone out a short distance in one piece without any damaging cracks and the amount of powder used must be gauged very skilfully.

SECONDARY BLASTING

It is usually necessary to do more or less secondary blasting of large boulders and chunks to facilitate shovel and crusher operation. This may be done by either blockholing or mudcapping (dobying), as described in Chapter XIX.

The former method is usually cheaper and safer, especially if several shots must be fired at once. A gelatin dynamite is preferable to a granular one, particularly when part cartridges are used, as it removes the hazard of loose powder being scattered about to be exploded by friction or sparks. However, the high count Du Pont "Extras" are widely used because of their economy. All blockholes should be tamped.

Mudcapping is used when drilling equipment is not available or when the rock is very hard, such as trap rock. If several shots are fired together, there is danger that one charge will dislodge another and scatter the unexploded dynamite among the broken rocks.

Cap and fuse are usually used, although electrical firing is practical and much safer if several shots are to be made at once. A shot firer should not be expected to light an excessive number of fuses, and all fuses should be cut sufficiently long to allow the men time to reach a shelter. It is a good safety rule to light a capped signal fuse 1 ft shorter than the regular blockhole fuses just before the men start lighting the blockholes. The cap must be placed where it will not endanger anyone when it goes off and the men should stop lighting and go to a shelter as soon as they hear the signal cap explode.

CHAPTER XV

BLASTING IN STRIPPINGS AND OPEN PITS

Stripping consists of removing any sort of material of little or no worth from the surface in order to expose a more valuable material underneath. The material removed may be soil or earth of varying degrees of hardness, frozen ground, hardpan, or rock of any kind which has no value to the operation being undertaken.

The exposed substances sought are mined, quarried, or worked as open pits. In this country they comprise coal, ore, stone, clay, and similar materials.

BITUMINOUS COAL

Stripping. In the stripping of bituminous coal, it is usually necessary to use explosives so as to remove the overburden, and present-day practices employ the use of both vertical and horizontal holes for blasting. The latter are used wherever conditions are favorable because they have contributed to a lower over-all blasting cost, but the rock formations overlying the coal govern the type of hole to be used.

For the successful use of horizontal holes, the coal must be overlaid with a stratum of shale or soft slate as horizontal drills are not yet developed to the point where they are practical in hard rock. The drills are of the auger type with extensions from 6 to 10 ft long and can cut 5-in. diameter holes in some soft materials at speeds as high as 9 to 12 in. per minute; 5 to 6 in. per minute is not at all unusual. Horizontal holes are drilled perpendicular to the face and their depth will vary from 30 to 75 ft according to the width of the cut taken. The spacing may vary in different operations from 10 to 30 ft depending on the characteristics of the overburden, and the equipment available. The holes should be started 3 or 4 ft above the top of the coal seam if possible, as the somewhat flexible construction of the sectional drill tends to make it drift downward and the charge of explosive should preferably be kept 12 to 18 in. above the coal to prevent crushing it. When the soft stratum overlying the coal is not

thick enough to permit starting a hole this high, the usual practice is to start and keep the hole as near the top of the soft material as possible.

It is seldom possible to blast limestone formations exceeding 5 ft in thickness satisfactorily with horizontal holes without excessive degradation of the coal below. Most attempts to use this system with heavy limestone layers have resulted in unwarranted wear and tear on excavating equipment. However, the position and relation of the various layers of overburden to each other has a very direct bearing on the possible results. There have been instances where 12 ft of limestone have been broken successfully in this way.

When the overburden is shallow, it is sometimes impractical to spread horizontal hole centers far enough apart to justify a solid column of explosives. In this case, the charge should be separated and a primer placed in each section with an air space left between. This will give better results than the use of stemming material between the charges. Great care must be used to tamp air-spaced holes very tightly, and it is suggested that 16 to 20 ft of tamping be used on holes drilled to a depth of 30 to 40 ft.

When the hard rock formations occur immediately over the coal or when the overburden is "top heavy," that is, when the coal is covered with 15 or more feet of shale or slate topped off with several feet of sand or limestone, the use of horizontal holes is impractical. There is either not enough space in which to drill the holes, or they will be placed so far from the hard rock that the explosive charge will not affect it. These conditions call for vertical holes.

Vertical holes are usually drilled with well drills and may vary in diameter from 4 to 9 in., depending on the equipment available. The present tendency is to use 8- or 9-in. bits, and spread the holes out as much as possible. Burdens from 24 to 50 ft and spacings from 25 to 35 ft have been used successfully where conditions were just right. As a general rule, thick layers of rock allow the use of wide drilling patterns, while thin layers require moving the holes closer together.

The depth of the holes will vary with the height of bank and the position of the rock layers. If there is a soft layer between the rock and the coal, it is customary to drill through the rock and a little ways into the shale or slate, but care must be taken not to drill so close to the coal that it is crushed by the blast. When the rock rests on the coal, the holes should be stopped far enough from the coal to prevent shattering it.

In the case of a "top heavy" burden, it is advisable to use two types of explosives in each hole, that is, a slow speed dynamite in the softer material and a faster one in the rock. If the hard rock is overlaid with soft material, the charge of explosives should not be allowed to extend above the top of the rock, in fact, it is better to stop the explosives charge about 2 ft below the top. Otherwise the energy of the blast may be wasted in the soft material which can normally be dug easily if the harder material below it is well broken. All holes either vertical or horizontal should be tamped to the collar whenever possible.

Both the characteristics of the overburden and the size and type of the equipment have a great deal to do with the kind and quantity of explosives used. The development of huge strippers with 20- and 30-yd dippers has greatly increased the burden per hole, reduced the explosive cost per yard, and removed the necessity for fine fragmentation in many operations. Generally speaking, it is necessary to blast much harder for a dragline operation than for a shovel, but here again, the size of the equipment is the final determining factor.

The dynamites used in this type of work include the "Red Cross Extra" grades, Du Pont Special Gelatins for very wet work, and occasionally "Red Cross" Blasting Free Running grades where the work is dry. The holes must be shot with electric blasting caps or "Primacord" and it is advisable to shoot as many at one time as possible in order to get the cumulative effect of several charges. There is such a wide diversity in the character of the overburden and in the equipment used for drilling and excavating that it is impossible to try to make definite recommendations covering spacings, burdens, or depths of drill holes, or grades and amounts of explosive used. Each operation is a separate problem which can only be worked out on the ground.

Mining. In many cases the bituminous coal which has been stripped is dug without blasting. Where blasting is practiced, the majority of operations use pellet powder and electric squibs. In the others, a wide variety of explosives is used, either of the ammonia dynamite type or, where the holes are wet. the "Gelex" grades or low strength Special Gelatins.

ANTHRACITE COAL

Stripping. Anthracite, when found in reasonably flat seams, is stripped by methods similar to those used for bituminous

coal, except that large diameter horizontal holes are seldom, if ever, used. However, much anthracite occurs in steeply pitched veins overlaid with hard rock, and in such cases the stripping is usually accomplished by the benching method of quarrying.

The majority of the holes are drilled vertically and will vary in diameter from 2 to 9 in., depending on whether they are drilled with wagon drills or well drills. The 6-in. diameter is the most common and the burdens and spacings are about the same as would be used in quarrying the same rock, that is, shale, sandstone, trap, etc. The depths will vary from 10 to 100 ft. Snakeholes drilled with tripod or wagon drills are also used and may be sprung or not, depending on the conditions. Large horizontal auger type drills are pretty generally ruled out by the severe pitch of many of the seams.

Many anthracite strippings recover coal that is too close to the surface for safe underground mining and frequently the location and extent of this coal is very much in doubt. This is particularly true where the underground workings have been abandoned for 50 years or more. Under these conditions, the blast is liable to break down into the old workings without doing much useful work on the overburden.

The type of rock determines the kind of dynamite used and "Red Cross Extra" 30 to 60%, Du Pont Special Gelatin 40 to 60%, and "Gelex" No. 1 and No. 2 will meet practically all conditions. As is the case in bituminous stripping, the characteristics of the rock and the drilling and digging equipment govern the type and quantity of explosives used to such an extent that it is not feasible to make hard and fast recommendations. Each case must be decided on its own merits.

Mining. As in the case of bituminous coal, considerable anthracite is dug without blasting, but where explosives are used, 40% "Red Cross Extra" and 40% Special Gelatin are by far the most common grades.

IRON ORE

Stripping. The stripping of iron ore bodies is usually accomplished by methods similar to benching in quarries with the banks averaging 25 to 40 ft in height. The overburden varies widely and includes loam, sand, hardpan, "bouldery" gravel, sandstone, paint rock, and taconite. Practically all sizes of holes, both vertical and horizontal, are used, with an occasional coyote tunnel.

In easier breaking rock, vertical holes may be drilled with either wagon or well drills. These are often sprung and loaded with "Red Cross" Blasting No. 2 and No. 4 Free Running if the work is dry, otherwise, with 20 to 40% "Red Cross Extra" or 25% Gelatin. Single rows of holes are generally preferred in order to get the full benefit of the back break. Occasionally, horizontal holes are drilled with wagon or auger-type drills, and in "bouldery" formations, gopher holing may be practiced.

Paint rock, which is usually laminated, may be shot very successfully with well drill holes loaded with "Nitramon" No. 2 or 40% "Red Cross Extra." The harder rocks like sandstone and taconite are practically always well drilled and shot with "Nitramon" A or B, 40 to 60% "Red Cross Extra" or Special Gelatin. All blast holes either horizontal or vertical should be well tamped to the collar and shot with electric blasting caps or "Primacord." Multiple hole shooting is preferred. As usual, the kind of overburden and the drilling, digging, and transportation equipment must be considered in determining the grade and amount of explosives to use.

Mining. After stripping, soft ores may be blasted with either vertical or horizontal holes. In the former case, the holes are often sprung and loaded with "Red Cross" Blasting Free Running grades in dry work; otherwise "Red Cross Extra" or Special Gelatin of low strength is used. Recently some operations have been very successful in blasting iron ore with 6 in. auger-type horizontal holes loaded with 5 in. diameter "Nitramon" No. 2. Of course, "Nitramon" will work equally well in vertical well drill holes. Harder ores will require 6 or 8 in. well drill holes and should be blasted with "Nitramon" A or B, "Red Cross Extra" 40 to 60%, or Du Pont Special Gelatin 40 to 60%.

MISCELLANEOUS MATERIALS

Stripping. Where the material to be stripped is only easily dug soil of a few feet in thickness, explosives are not economical, but where the digging is harder, the use of "Red Cross Extra" 20% to loosen the material is advised in much the same manner as in subsoiling (see Chapter XIX). Where only a thin layer of hardpan interferes with digging, the explosive should be loaded in the layer of hardpan. In frozen ground the holes may be sunk vertically just through the frost, but in many instances better results are obtained by flat

holes, sometimes called slab shots, run in immediately against the under side of the frozen crust.

In deeper stripping, a vertical face is carried in much the same manner as a quarry face. Vertical holes are sunk almost as deep as the stripping by means of soil augers, churn drills, tripod drills, or even well drills, depending upon the facilities and the character of the material. The work is much like quarry practice, except that the material is usually softer, the lower grades of dynamite are used, and not so much explosive is required. "Red Cross Extra" 20 to 30%, "Red Cross" Blasting No. 2 or No. 3 Free Running, and the RR granulation of B Blasting Powder are the explosives most frequently used. The last mentioned grades are usually shot in sprung holes and cannot be used if the work is wet.

In many cases horizontal drilling and snakeholing are practiced in much the same manner as in quarry work. The explosive should be used in rough paper cartridges or in tamping bags so that it can be conveniently loaded into the sprung hole.

Owing to the variable conditions encountered in stripping work, no specific rules as to the amount of explosive required and the spacing of the holes can be given. Many blasters on new work use as a rough basis for the first shot the following, and then regulate the balance of the work according to the first results: for holes up to 7 ft deep, space apart and back from the face equal to the depth; for holes 8 to 20 ft deep, space apart and back 8 to 12 ft. Holes of 1¼ in. in diameter are generally loaded half full of explosive for the first trial shot.

Where it is desired to use gopher holes and heavy charges of blasting powder, the hole can be driven as follows: with a punch bar drive a hole large enough to hold a 1″x 8″ cartridge of dynamite. Explode a cartridge of "Red Cross Extra" 30 or 40% in this hole and dig out the dirt by means of a special narrow shovel on a long handle. Drive another hole in the bottom and repeat. These small holes should be, if possible, from 1½ to 2 ft deep for each one-cartridge blast. By this means a hole of from 6 to 8 in. in diameter can be driven to a depth of from 20 to 30 ft. It can then be sprung to receive a heavy charge of blasting powder. The powder can be loaded by means of a narrow wooden box on a long handle or by means of a V-shaped trough. This trough can be pushed back and forth so that the explosive will be worked into the back of the hole. The shovel and the loading box can be handled more easily if a cross bar is erected at the proper height in front of the hole and if the handles on the shovel and loading

box are long enough to give an appreciable leverage when these implements reach the back of the hole.

Sometimes the overburden may contain boulders of such a size that small tunnels will be the only method by which the charges can be placed. The tunnel method allows the removal of a fairly large-size boulder, and if one is encountered too big to be taken out it can be block holed.

Working the Pit. The quarrying of stripped stone has been described in Chapter XIV. The blasting methods for gravel, sand, clay, and other materials which are worked in open pits may be any one of several practices described in other portions of this book.

Frequently it is impractical to drill holes in these types of materials so that a common practice is to use gopher holes. The faces may be anything from a few feet to 50 or 60 ft high, and may have any slope from about 60 degrees up to vertical. Gopher holes are usually placed 10 to 15 ft apart and are put in relatively deeply.

A low velocity explosive is ordinarily best suited to this work, so black powder, either grain or pellet and the low velocity Du Pont "Extras" are recommended. In heavy compact materials where some fragmentation is needed it will be well to use the high velocity Du Pont "Extras" or the "Red Cross Extras." The amount of explosive to be loaded per hole can only be gauged from experience and from actual results. All holes should be tamped to the collar before firing and it is best to shoot several holes at a time with electric blasting caps.

CHAPTER XVI

BLASTING IN HIGHWAY AND RAILROAD CONSTRUCTION

The use of explosives in highway and railroad construction can logically be divided into the following classifications: (1) clearing and grubbing; (2) ditching and drainage; (3) excavation; (4) fill settlement; and (5) production of surfacing material and ballast.

Details of blasting procedure for clearing and for ditching are covered in Chapter XIX, and for production of surfacing material in Chapter XIV. Excavation and fill settlement are discussed in this chapter.

Grading methods for both modern highways and railroads are very similar and as highway construction consumes much the greater volume of explosives today, it alone will be considered in the following discussion.

EXCAVATION

The present tendency in highway construction is to reduce grades, ease up or eliminate curves, widen roadbeds, and in short do everything possible to facilitate rapid and safe transportation. Where economically possible, tunnels are driven for highways under conditions similar to those found on modern railroads. As a result, the explosives requirements for Class I highway construction are much greater than was dreamed possible a few years ago. Efforts are being made to provide improvements in highways commensurate with the tremendous increase in traffic anticipated in the future.

General Description. Highways are classified in the order of their importance as turnpikes or toll highways, primary roads, secondary roads, etc. The toll highways are usually four lanes wide, two for traffic in each direction, with a dividing parkway as shown in Figure 160. Grades are limited to a 3% maximum and curves to 6°. Many of the primary roads are part of the national cross-country highway system, are three and four lanes wide in places, and have limiting grades of 7%. Obviously these two principal types of roads use by far the major portion of explosives consumed by this construction.

McLaughlin Air Service

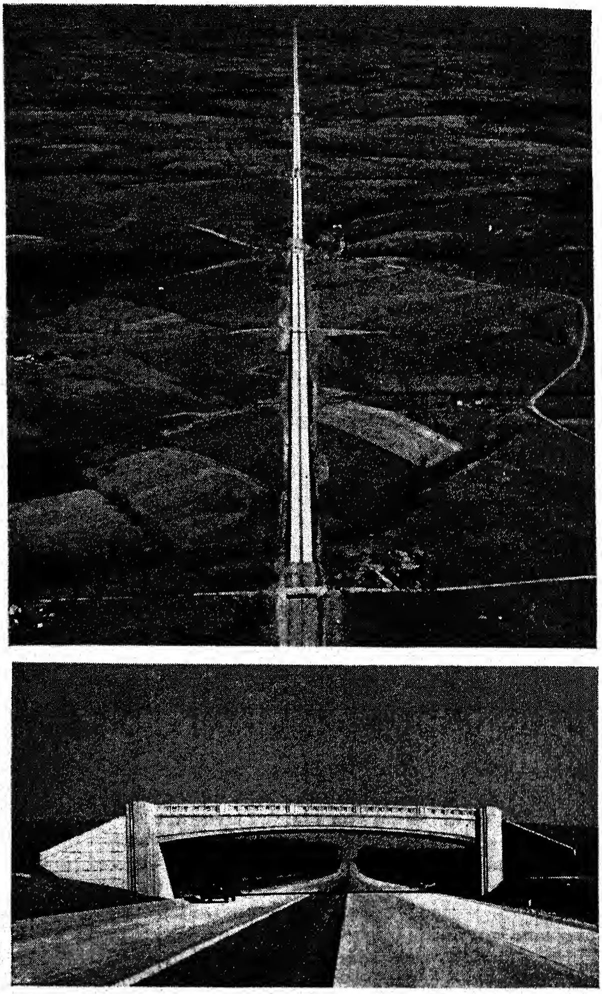


Fig. 160—Two views of the Pennsylvania Turnpike

In determining the location of the center line and grade line of a highway, an effort is made to keep the volume of excavation to a minimum consistent with the adopted limits for grades and curves. However, good practice dictates that volume of cuts should balance volume of fills within the limits of a reasonable haul of say 2,000 ft. (See Figure 161.) The material from the cuts, earth and broken rock is deposited in the adjoining fills in layers which, after thoroughly compacting with a roller, are not over 12 in. to 18 in. thick. The fills should just require all the excavated material. If not, the excess is "wasted" in some suitable area off the right-of-way. If more material is required it is "borrowed" from a designated

Fig. 161—Typical grade line showing cuts and fills

hill or other source nearby. This "borrow" is usually earth if at all possible, thus requiring no blasting. The fills when placed in this manner are thoroughly compacted and ready to receive the hard surface, usually concrete, as soon as the grade is finished.

Types of Cuts. There are two general types of cuts, a "thorough" cut where the excavation is made through a hill leaving a wall on both sides, and a "side-hill" cut where the excavation is made in the side of the hill leaving a wall on one side only. In this latter type, however, part of the section may be a fill in which the material must be compacted as described above. In side-hill cuts it is seldom possible to waste the material by throwing it down the hillside with heavy shooting as it is usually needed for fills.

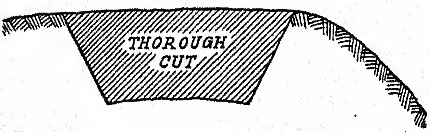


Fig. 162—A thorough cut

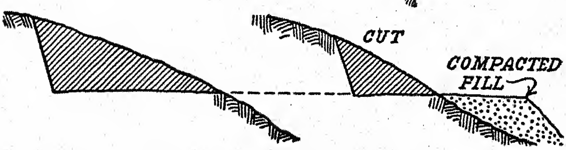


Fig. 163—Two types of side-hill cuts

Material encountered in road cuts varies greatly depending on the depth of cut and type of terrain traversed by the highway. Unless the country is very rocky and rugged, shallow cuts of less than 10 ft usually contain soft material such as earth, soft shale, or broken rock which can be removed without blasting. In deeper cuts rock is regularly encountered at some point before grade is reached or in hilly or mountainous country rock may outcrop on the original surface.

Method of Operation. Where possible the loose top material, unless it is less than 3 or 4 ft thick, is first removed with a shovel and truck or a power scraper. The modern tendency is toward heavier excavating and hauling equipment. Revolving shovels up to 2½ cu yd capacity and trucks handling 15 to 20 cu yd each are capable of stripping off all the overlying material and even digging some of the solid formation until it becomes so tight as to cause excessive wear and tear on the equipment. Where hauls are comparatively short, say not over 2,000 ft, power scrapers hauled by caterpillar tractors have proved very economical and effective. When the material in place becomes too tight to be picked up by a scraper, it is loosened by a "rooter." In such cases the scraper while loading is usually pushed by an auxiliary tractor in the rear. This method is particularly effective in stratified shale or decomposed, thinly stratified rock thus permitting more economical excavation of material which would otherwise require blasting.

In determining the method of blasting and particularly the depth of cut and area to be broken ahead of the shovel, the continuous operation of the loading and hauling equipment should receive first consideration. The depth in rock generally conceded to be most economical is 12 to 15 ft. Apparently the height of face of broken stone thus obtained is sufficient to fill the shovel bucket in one pass and no time is lost in trimming the pile. Also it is much easier to trim the slopes than with a deeper cut. Of course, if the total cut to grade is only 2 or 3 ft more, the entire depth should be taken in one lift, otherwise it is best to take two or more lifts.

With the modern tendency toward wider highways it is usually not difficult to provide ample working area for the shovel so that the empty haulage unit can be spotted at the shovel before the loaded one pulls away thus eliminating most of the lost time from this source. Under such conditions shovel production of 150 cu yd per hour is not uncommon. In some cases, particularly in side-hill cuts, a long face can be developed

parallel to the center line which also greatly facilitates movement of haulage equipment. With this arrangement also the shots can sometimes be made on a fairly open face, resulting in a saving of explosives if the desired breakage can be obtained. The above method is sometimes used in deep thorough cuts also which may be 100 to 300 ft wide at the top, where a long cut can be opened up along the center line or on either side, depending on the slope of the surface. This face is then worked as a quarry and pushed back laterally to the slope line. This method can be repeated on successive lifts until the cut becomes too narrow or less than 100 ft.

The thorough cut is then worked in the normal manner, that is, with the shot extending the full width and for sufficient length to provide at least one day's shovel yardage. (See Figure 164.) From a blasting standpoint, however, the shot should be made as long as possible. On the sides and the advanced end of every shot there is bound to be some overbreak, the amount depending on the type of material and spacing and depth of holes. On the sides of the cut the holes can usually be kept the proper distance away to avoid breaking into the slope line. On the end of the shot, however, the ground

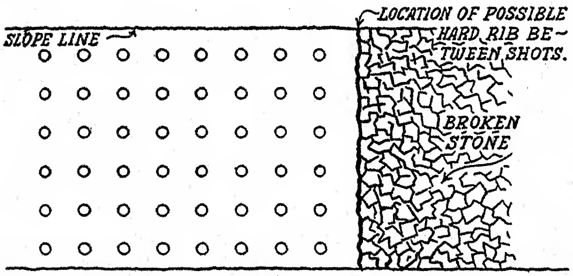


Fig. 164—Typical drilling layout for blasting rock for a thorough cut

may be disturbed for several feet ahead making it impossible to get the first row of holes in the next shot close enough to break the intervening material particularly in the bottom. This leaves a hard rib between shots which may cause some delay and require reblasting. This condition can be relieved somewhat by a slight change in drilling and loading the end holes as described in the following paragraphs.

Drilling. As a result of the rapid development of air drills during the past few years, wagon drills (see Chapter VII) are used almost exclusively for rock work on highways. The well drill has little application due to higher drilling costs, prevalence of shallow cuts, necessity for better breakage, and present high-speed methods. It should, however, be given consideration in deep side-hill cuts where a fairly open face can be developed and shot to grade in one operation and where sufficient breakage can be obtained by this method or where the material is to be thrown over the hill and wasted. Hammer drills are used on small jobs and for secondary shooting.

Wagon drilling provides relatively low unit costs which permit fairly close spacings of holes, hence better distribution of explosives throughout the mass of rock and hence better breakage. Usually holes are finished at 1¾ in. to 2¼ in. diameter, and the normal depth requires the use of only two to three lengths of steel depending on height of the drill derrick or mast. Detachable bits have been found most practical for this type of work as they can be changed on the job thus eliminating much handling of steel. Drilling speeds vary greatly depending on rock encountered. In limestone and sandstone, figures of 40 to 60 ft per hour are not unusual, increasing to 100 or 125 ft for decomposed rock and shale.

Drill hole spacings vary all the way from 5 by 5 ft to 8 by 8 ft and generally speaking best results have been obtained by column loading rather than by springing and using a concentrated load in the bottom. Holes are drilled 2 to 3 ft below shovel grade in order to insure breaking the bottom. Bottom breakage may require closer spacing than the upper portion of the rock. (See Figure 165.) About the only conditions to

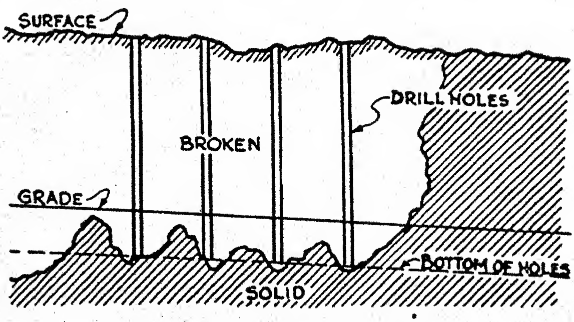


Fig. 165—Drilling below grade to insure breaking entire bottom to grade

which springing and wide spacing are adaptable are in laminated material requiring only a shaking up, or in extremely hard rock where drilling costs are excessive. Springing can sometimes be used to advantage in the first row of holes adjacent to a previous shot in order to break the bottom through the heavy burden usually encountered and help eliminate the hard ridge between shots. Overbreak can sometimes be reduced by cutting the spacing on the last row and stringing the charge along the hole by deck loading if necessary.

Explosives. The simplest method of loading holes is to use a single charge, part or all of which may be slit and tamped in the bottom. Explosives cartridges should fit the hole diameter as closely as practicable, the most general choice being 1½ in. or 1¾ in. for wagon drill holes. Use of 5 to 7 ft of stemming on top of the charges will usually prevent flying material but higher loading or even deck charges may be necessary to obtain better top breakage.

Types of explosives applicable to highway blasting cover a wide range. Du Pont 40% Special Gelatin is very satisfactory for medium hard limestone, sandstone, and shale especially where exposure to water may extend over several days. "Gelex" No. 1 or No. 2 will usually show a saving over gelatin, provide sufficient water resistance for one or two days, and sometimes even better execution if the material is not too hard. Du Pont "Extras," usually C or D, and 40% "Red Cross Extra" are suitable in easier breaking material under reasonably dry conditions. For loading in sprung holes where a heaving effect is desired the "Red Cross" Blasting Free Running grades are often used instead of black blasting powder.

The loading ratio or amount of explosives required per cubic yard of rock broken depends on the type of material, depth of holes and type of explosive. It is also determined by the location of the blast, that is whether it is a "tight" shot as in a thorough cut or whether it is on an open face, and also by the type of equipment and use for the blasted material.

Under average conditions in a thorough cut, as described above, using 12 to 15 ft holes in medium hard limestone or sandstone loading 40% dynamite, a representative figure is 0.65 to 0.75 lb per cubic yard. In laminated rock or shale this factor could be reduced to 0.50 or even 0.40. In harder material it would approach or even exceed 1.0 lb per cubic yard and a stronger dynamite would probably be required

to give satisfactory breakage. In some cases it may be necessary for operating reasons to use deeper holes in a tight shot, say 25 to 40 ft. Such conditions cause a marked increase in explosive requirements with factors of 1.25 to 1.75 lb per cubic yard of rock depending upon hardness of material and strength of dynamite.

Open face shooting requires less explosive, the factor depending largely upon the type of rock and not so much on the depth of holes. Factors usually run about 0.3 to 0.6 lb per cubic yard.

Firing. The trend in highway blasting is toward larger shots requiring more electrical power than furnished by a blasting machine. Under favorable conditions a Du Pont No. 50 Blasting Machine will usually handle up to 200 holes hooked up with five equal series in parallel. Larger shots of several hundred holes are not uncommon, requiring either a portable lighting plant or a power line. The most satisfactory method is to use series of 25 to 35 caps each, these series hooked in parallel according to methods and calculations given in Chapter X.

FILL SETTLEMENT

In locating modern highways to the best advantage it is often necessary to route them across swampy areas and in such cases it is necessary to take special measures to provide a solid foundation for the fill material. The use of explosives for this purpose has solved the problem very satisfactorily in certain sections during the past few years. Four general methods have been evolved.

Ditching Method. The first, or Ditching Method, as illustrated in Figure 166, has been used where the amount of muck involved was comparatively shallow, not in excess of 12 to 15 ft and consists of blasting as large a ditch with Ditching Dynamite as possible along the center line of the projected highway.

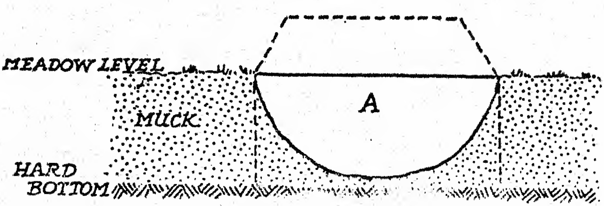


Fig. 166—When the muck is shallow a large ditch (A) is blasted to allow the fill material to penetrate to hard bottom

Such a ditch may be even as large as 50 ft wide and 8 to 12 ft deep. It is usually shot in comparatively short sections into which is dumped without delay enough fill material so that the weight causes complete settlement to hard bottom.

Three distinct loading systems are used to blast these large ditches, as covered in Chapter XIX, namely: the Cross Section Method, the Relief Method, and the Post Hole Method.

The blasting of such a ditch has two functions—to throw out as much material as possible, and to liquefy and stir up the remainder so that the weight of the fill will readily push aside what has been left between the bottom of the ditch and a firm foundation.

It is, of course, taken for granted that the class of material to be placed in the fill has a great deal higher density than that of the muck which is being removed. Fills placed in this manner are ready for their hard surface in a comparatively short time.

Under-Fill Method. The second, or Under-Fill Method, shown in Figure 167, calls for placing the required fill on top of the marsh and loading the dynamite in the muck underneath. It has usually been customary to use dynamite first to break up and disintegrate the meadow mat prior to placing the fill, because after this mat has been broken, the weight of the fill material brings about an even, natural settlement. Explosives are then placed beneath the fill by means of casings driven into the muck.

The amount of dynamite, the number of rows of holes, and the depth of the holes are dependent on the depth of the mud and the height of the fill. The force of the explosion in the muck pushes it in all directions. It is confined from below by

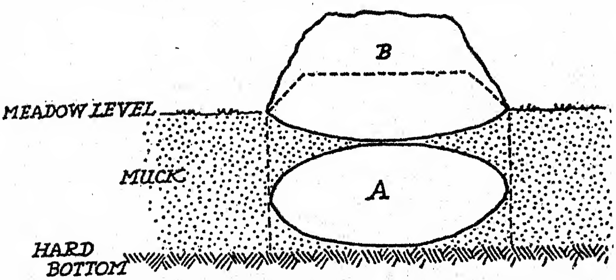


Fig. 167—When the muck is deep and a sandy fill material is used, the fill (B) is placed on top of the muck; charges under the fill blast the hole (A) and (B) is allowed to settle to hard bottom

hard bottom and from above by the solid fill material; hence it is pushed to the sides and the fill settles into place.

Here, again, the dynamite has two functions—to create a cavity for the fill to drop into, and to stir up and semi-liquefy the mud surrounding this cavity, in order to increase the rapid settlement of the fill. This method has been most generally used up to the present time. Figures 168 and 169 are illustrations of this second method of settling fills through deep, unstable material.

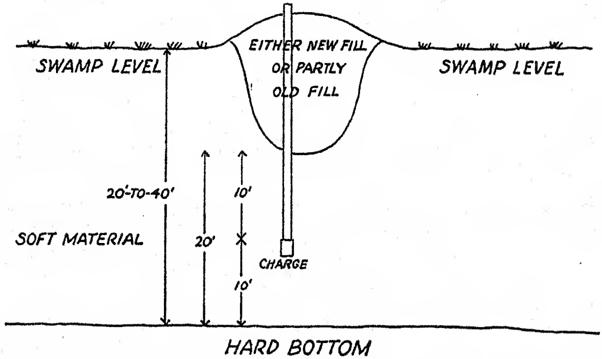


Fig. 168—The method used in swamps deeper than 20 ft; requires power-driving equipment

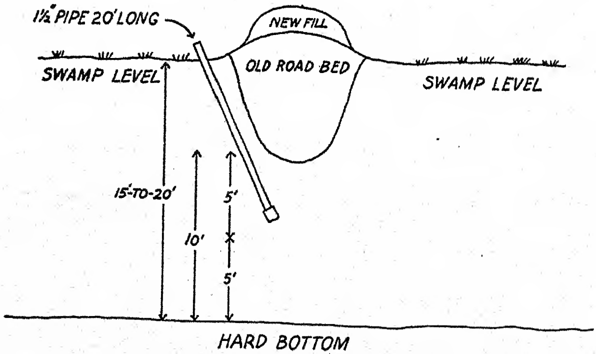


Fig. 169—Simplest in swamps not over 20 ft deep where conditions will allow a 20-ft length of pipe to be forced or driven by hand; requires no other equipment than hammers, pipe cutter and other small hand tools

Relief Method. The third, or Relief Method (see Figure 170), is partly a combination of the first and second and involves shooting a ditch on either side of the fill after it has been put in place. It is particularly valuable where the fill material is of the clay type. Sand and gravelly material will flow more or less readily into holes made by dynamite, but clay fills set up a bridging effect and act as a compact, solid body.

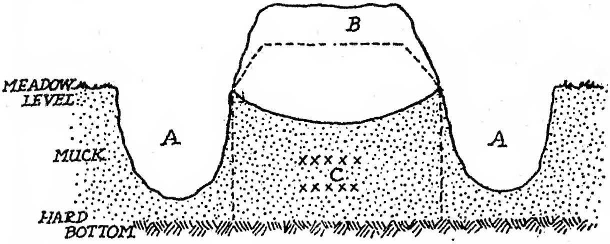


Fig. 170—When the fill (B) is clay, ditches (A) are blasted to relieve the side pressure, allowing the fill to push out the muck underneath. Sometimes auxiliary charges are exploded at (C) to augment the movement in a lateral direction

These ditches thus relieve the pressure so that the weight of the fill can more easily push out the underlying mud. When it is deep, extra loads must be placed close to the ditch lines below the bottom of the fill. These charges tend to liquefy the mud and give the weight of the fill increased opportunity to settle further with its own weight.

Toe-Shooting Method. The fourth, or Toe-Shooting Method, consists of shooting the muck ahead of the advancing fill. Fill material is then dumped into the blasted area, advancing with a "V" point, until a sizeable mud wave is pushed up. (See Figure 171-A.) A surcharge of fill is added, bringing the fill above grade while charges of explosives are placed around the toe of the fill. When these charges are detonated, settlement is obtained as shown in Figure 171-B. The fill is then built up again and the operation repeated. (See Figure 171-C.)

Care must be taken to maintain the point of the fill in a "V" shape. (See Figure 171-D.) Considerable expense and annoyance have been caused on various jobs using this method, due to the failure of the contractor to build this shaped dump, with the result that the muck or displaced material was driven ahead rather than to the sides of the advancing fill and built

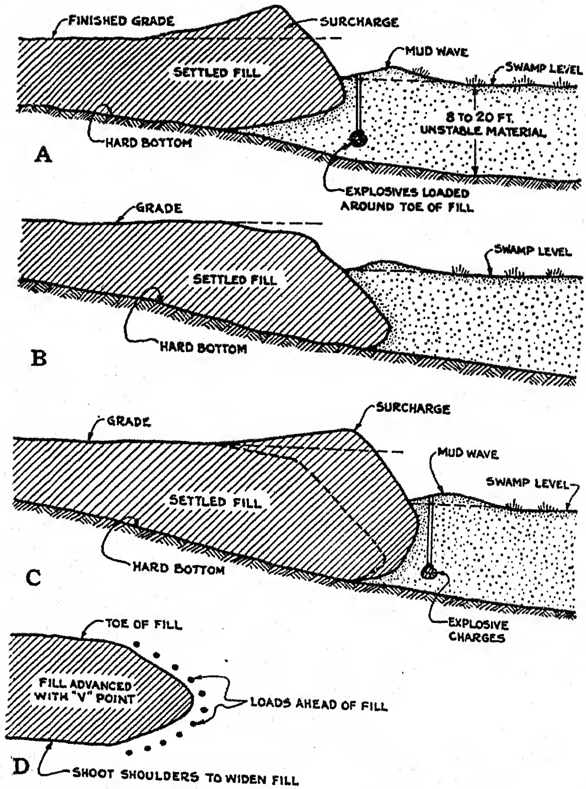


Fig. 171—Fill settlement by the toe-shooting method

up to unmanageable proportions. Even when the fill is advanced in a "V" point, the displaced muck might build up in a wave that will require additional blasting or removal by mechanical means.

The depth and composition of the unstable material will govern the amount and spacing of the explosives charges. Where the unstable material is a fine silt, much lighter charges will be necessary than where the unstable material is a heavy

peat. For the initial charge, under average conditions, explosives charges approximating 1½ lb per ft of depth of muck, spaced 6 to 8 ft apart, should be loaded around the "V" point of the fill. These charges should be placed as near to the toe of the fill as possible and at a depth equal to ⅔ of the depth of the muck. Thus with a depth of muck of 18 ft, a 25 lb charge of explosives at 6 to 8 ft centers loaded 12 ft deep should constitute the first trial shot. Judging from the results of this blast, the loads or spacing may be altered to produce the desired results.

The interval between blasts will vary according to the nature and depth of the unstable material. With a fine silt the fill can probably be advanced a distance equal to the depth of the unstable material. With a heavy peat it will probably be necessary to blast at intervals equal to ½ the depth of the unstable material. The height of the mud wave will also affect the interval between the blasts. As the mud wave builds up it will be necessary to blast oftener and also to increase the size of the loads. A top charge loaded in the mud wave materially assists in scattering it and this charge can be loaded and fired along with the bottom charge.

Because of the many factors involved in this type of work and conditions encountered, there are necessarily many variations, combinations and adaptations of these methods.

Explosives. Ditching Dynamite is a very satisfactory explosive for this type of work if the propagation method of blasting can be used. For electric firing, however, 40% to 60% Special Gelatin or "Gelex" is recommended.

CHAPTER XVII

BLASTING IN TUNNELS AND SHAFTS

TUNNELING

The tunneling operations described in Chapter XII were designed for driving drifts and crosscuts in mines. Those discussed in this chapter apply to construction work such as railroad, vehicular, and water tunnels. These, as a rule, cannot serve any useful purpose until they are 100 per cent complete and therefore must be advanced at the greatest speed compatible with safety and efficiency.

Wet drilling which reduces the dust is usually practiced and portable jumbos mounting several drills are used to expedite the drilling and to serve as platforms for loading and connecting up the rounds. The drilling platforms are usually made to fold up against the frame of the jumbo when not in use and space is provided on them for drills so that much time is saved in moving the drilling equipment in and out of the heading. High-speed mucking machines are employed to load out the broken material in a minimum of time and the track and rolling stock must be especially constructed for high-speed, safe operation. Finally the ventilating system must be designed to furnish a satisfactory supply of fresh air to the face at all times and to remove the smoke and fumes from the blast as quickly as possible.

As the explosive must necessarily break ground in tight headings and even in hard rock, the higher strengths are usually used. The explosive must also be easy to handle, plastic, and cohesive for easy tamping and high loading density, and its fume properties must be of the best so that, with efficient ventilation, work can be resumed at the heading within a reasonably short time after blasting. Consequently the explosives most commonly used are Du Pont Gelatin, Du Pont Special Gelatin, and the "Gelex" grades. The rounds are always fired with instantaneous and delay electric blasting caps.

Tunnels vary in size according to their purpose. Water supply and sewage disposal tunnels may be as small as four feet in diameter while water diversion, railroad, and vehicular tunnels may be as great as forty feet in diameter.

The operation of tunneling is so broad in scope, due to variations in the size and shape of tunnels and methods by which they are driven, that a comprehensive discussion of blasting methods could comprise the subject matter of a complete volume. The only practical treatment feasible for this handbook is a brief outline of the basic methods employed.

Drilling Cut Holes. It is axiomatic in tunnel driving, first, that the round cannot pull unless the cut comes out properly, and second, that the advance per round cannot be greater than the depth of the cut. Therefore, the proper placing of the cut holes is the first and most important step in drilling any round. The V and pyramid cuts are almost universally used in construction tunnels, although occasionally in driving very small tunnels, or when one wall of the tunnel coincides with a well-defined parting, the draw cut is used. All of these cuts are described in Chapter XII.

Prior to the general use of jumbos it was customary to drill the V or wedge cut so that a line drawn through the points of the V's was perpendicular to the greater dimension of the tunnel. With jumbo drilled rounds it is now the practice to place them in the most logical position, as indicated by the slips and seams in the face. In thinly stratified rock with well-defined partings it is better to drill the holes across the strata as the cut will break cleaner than with holes drilled parallel to the lay of the formation.

Regardless of the position of the cut holes, the greater their slant or lift, the easier they will pull. The most efficient angle is 45° to the face as this gives the greatest volume in the V per foot of drilling, but it is seldom practical or possible to take such a large angle. Therefore the driller should give the cut holes as much lift as possible considering the conditions at the face and the desired depth of the round. Deep rounds, because of the tightness of the cut, are harder to pull and require more explosives per yard, so it is better to plan on a little shorter round and be more certain of pulling the full depth every time. For instance, it may be possible to pull three 8-ft rounds a day where only two 10-ft rounds can be completed in the same time.

Method of Pointing Cut Holes. The success of any round is dependent upon the proper placing of the cut holes which should either meet at a definite point behind the face, or in some kinds of rock, be a definite distance apart at the toe.

The following is a method that may be used to point the holes properly.

First, locate the center of the face by means of roof sights and paint a vertical line through it (D-Figure 172). Then paint a vertical line on each side of the center and equidistant from it (A and C) for the location of the starting points of the cut holes. In tunnels 16 ft or less in width A and C should be slightly less than halfway from the center line to the rib, in wider tunnels they should be about 4 ft from the center. These distances hold for average conditions, but in special cases it may be advisable to drill wider or narrower cuts.

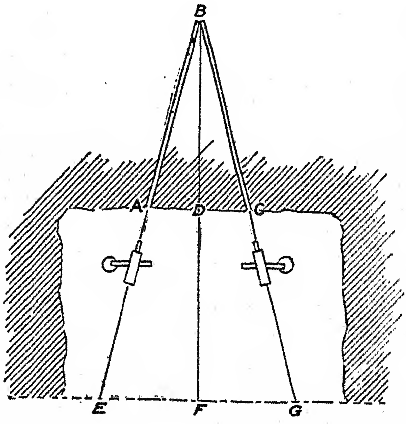


Fig. 172—Method of directing cut holes that are to meet

Assume that the holes are to meet at B, a definite distance back of the face. Then the triangle ABC represents the proposed cut, with the distance AC the width, and DB the depth. Lay out the center line on the floor of the tunnel so that the distance DF is equal to the proposed depth of the cut DB. Next lay out the line EFG perpendicular to DF at F, and mark the points E and G on the floor so that FE and FG are each equal to AC. Mark the lines EA and GC on the floor and set the drills up so that they are at the same height from the floor and directly over these lines. If the drills are started on points A and C and maintained over the lines EA and GC until they have penetrated a distance equal to EA, the holes will come very close to meeting at the desired point B. Of course both drills must be held at the same vertical angle with the face. The remaining cut holes can be lined up with drill rods placed in the first pair of holes. Pieces of drill steel will be found most convenient to use in laying out the lines DF, EG, EA, and GC.

A similar procedure may be used when it is desired to have the cut holes bottom a certain distance apart. Determine the line EA and GC as already directed. Assume the holes are to bottom 4 in. apart, as in Figure 173. Place the point of the drill at C and move the shank at G, 2 in. toward the center (H-Figure 173). Similarly, with the drill point at A, move the shank of the second drill from E 2 in. toward the center. The two drills can then be lined up over these two new lines and the toes of the holes will be very close to 4 in. apart when the two holes have been drilled a distance equal to HC.

It is good practice to have the cut holes extend 6 or 8 in. farther into the rock than the other holes in order to help the rest of the round to break clean. The speed demanded in modern tunneling usually precludes the possibility of returning to the face to make sure that the cut has pulled completely, so it is better to drill a few extra cut holes to insure a well-broken cut than to run the risk of pulling a short round.

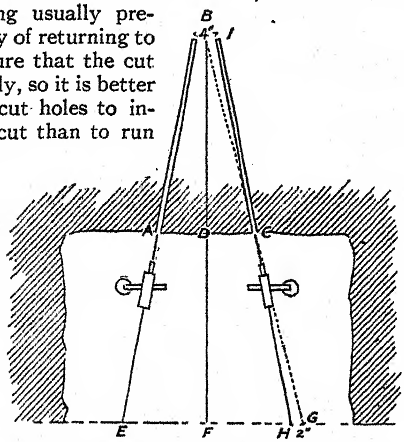


Fig. 173—Method of directing cut holes that are not to meet

Relief and Trim Holes. After the cut holes have been properly placed, care is necessary in locating and pointing the relief and trim holes, so that the former will enlarge the opening formed by the cut in a logical and orderly manner, and the latter will pull the full cross section of the face without the necessity of trimming and with a minimum of overbreak. Rock varies so much that it is impossible to predict the number of holes necessary to pull a round of any given cross section and depth. The blaster must start off with a round that seems reasonable, based on his previous experience, and make changes as indicated by the results. While the burden that any hole will pull is determined by the rock, it should not exceed two to three feet as a general rule. The trim holes will normally have the least work to do,

but in most rock they cannot be spaced more than three to three and a half feet apart and still produce a reasonably smooth outline.

TUNNEL DRIVING METHODS

Formerly, the size of the tunnel and the type of ground through which it was being driven influenced the choice of the driving method; for instance, the top heading and bench method used to be the standard American system for large tunnels in good ground. More recently, the type of equipment available has had more weight in determining the method. The four most common methods are described below and a round representative of each one is shown. It should be realized that there are almost as many tunnel rounds as there are tunnels and the ones sketched are merely indicative of the general method of attack.

Full Face Method. As the name indicates, this method uses a round designed to pull the full cross sectional area of the face at once. It has always been used for small tunnels but since the development of the multiple drill jumbo and really efficient mucking machines, it has been pretty generally adopted for tunnels of any size in good rock. Today, it is by far the most widely used method. The drill carriage, or jumbo, with the platforms extended and the drills in the drilling position practically fills the whole tunnel, so naturally all mucking must be completed before any drilling can be started. This does not delay the work, as modern mucking devices clean up the broken material very rapidly and drilling can start almost as soon as the jumbo is in place. The design of the jumbo and the round that it is to drill is an art in itself and the time and care spent on it will be well repaid in smooth and rapid progress when driving starts.

The figures by the holes in the following sketches refer to the firing order; those marked "x" are primed with instantaneous electric blasting caps and shoot first, while those designated 1, 2, 3, etc., follow in order, being primed with first, second, or third period delay electric blasting caps.

Figure 174 shows a jumbo drilled round used in a 12 by 14 ft tunnel. The round comprised 43 holes including a four hole pyramid cut with a four hole baby cut to insure pulling full depth. The average advance in this operation was eight and one-half feet per round. This jumbo carried five drills, three on the top and two on the lower part.

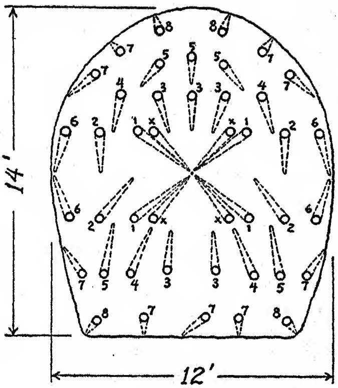


Fig. 174—Full heading jumbo drilled round using double pyramid cut

A round used in a large tunnel is shown in Figure 175. This was 22 by 32 ft in cross section and required 93 holes with a double V cut. The average advance per round was 12 ft and the jumbo mounted 13 drills.

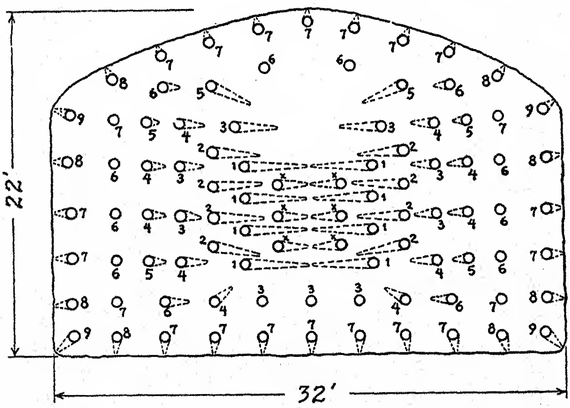


Fig. 175—Large full heading jumbo drilled round using double V-cut

Heading and Bench Method. As previously mentioned, this method was standard practice for many years. It consists in driving a heading at the top of the tunnel about eight feet high and the full width of the proposed opening. The lower or remaining part of the tunnel is removed in one or more steps or benches. The bench is usually carried one round behind the face or heading.

The heading round consists of a V or pyramid cut and the necessary relief and trim holes, in other words, a typical drift round. Drilling is ordinarily done from bars or columns and may be carried on while mucking is in progress if the previous round was loaded and fired so that most of the muck from the heading was thrown clear of the bench. Either vertical or horizontal holes may be used in the bench; in the former case the holes may be drilled as soon as the top of the bench is mucked off; in the latter case, drilling must wait until the mucking operation has been completed.

Figure 176 shows a typical top heading and bench round using vertical holes in the bench. The holes marked "x" are loaded with instantaneous electric blasting caps and those marked 1, 2, 3, etc., with the corresponding periods of delay electric blasting caps.

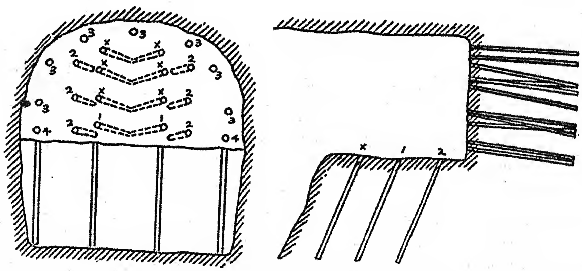


Fig. 176—Top heading and bench round

When horizontal holes are used in the bench, it is sometimes the practice to load the holes primed with instantaneous caps rather heavily so that the rock from the first shot in the bench will be thrown up to meet the rock from the cut in the heading and prevent it being thrown so far back.

Center Heading and Ring or Pilot Tunnel Method. This method has been used in driving many large tunnels. A drift

8 by 8 ft or 10 by 10 ft is driven in the center of the proposed tunnel by conventional methods. The drilling may be from a jumbo or by means of columns or bars. As a rule this heading is driven all the way from portal to portal before any enlargement is attempted, although this is not necessary if some way can be devised to dispose of the muck from both the drift and the enlargement at the same time.

Holes for the enlargement are ring drilled from posts or bars at the same time as the heading. They are usually drilled in sets four to five feet apart, perpendicular to the axis of the tunnel, and arranged so that the toes are three to four feet apart at the perimeter of the full cross section. Templates should be provided so that drilling can be accurately done and the center heading must be large enough to allow the use of drills long enough to reach the outside limits of the full tunnel.

Figure 177 shows a typical arrangement for tunneling by this method. When the rings are blasted, it is the usual practice to shoot the lower half a few sets ahead of the top half in order to give the short side holes a better chance to break. Each round will consist of several rings, the first being loaded with instantaneous electric blasting caps, the second with first delays, the third with second delays, and so on.

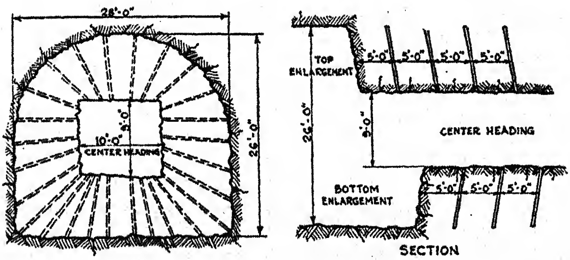


Fig. 177—Large railway tunnel driven by center heading and ring drilling method

Pioneer Tunnel Method. Long railroad tunnels have made use of this method, often in combination with the pilot tunnel method just described. A small drift, say 8 by 8 ft, is driven parallel to and about 50 to 75 ft away from the main tunnel; this is called the pioneer tunnel. It is normally pushed considerably ahead of the face in the main tunnel, thus giving

warning of any major change in the rock in ample time to allow for different procedure in the main heading. Also, about every 1,500 ft, crosscuts are driven from the pioneer to the line of the main bore, opening up two more faces from which the pilot or full main heading may be driven. When the pilot tunnel method is being used, enlargement of the section between two crosscuts may be started as soon as the two pilot headings meet. The pioneer tunnel not only serves to open up a large number of faces in the main tunnel to allow faster driving, but also furnishes a muck haulage way and a means of improving ventilation at the various headings.

Figure 178 illustrates this method diagrammatically. The Rogers Pass Tunnel in British Columbia, the Moffat Tunnel in Colorado and the Cascade Tunnel in Washington were all driven by this combination of pioneer and pilot tunnel methods.

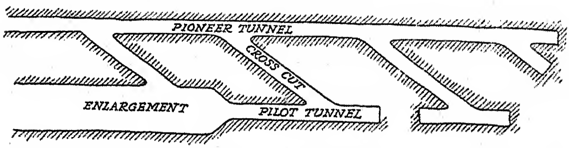


Fig. 178—Driving large-size tunnel with pioneer and pilot tunnels

Loading, Tamping, and Firing. These subjects are discussed generally in Chapters IX and X, so only those points which apply specifically to tunneling will be considered here.

Regardless of the care used in drilling a round, it cannot be expected to pull effectively unless care is taken to load the holes properly. As has already been stated, gelatin grades are commonly used in tunneling because of their density, plasticity, and excellent fume qualities. Specifically, 40% and 60% Special Gelatin and "Gelex" No. 1 and No. 2 have proved best adapted to this work. In order to get the desired high loading density, the cartridges should be slit and pressed into place one at a time, using a wooden tamping stick and short, firm strokes.

The possibility of cut-off holes in tunnel rounds makes it desirable to place the primer as close to the bottom of the hole as possible. Usually it is loaded as the second cartridge from the bottom with the cap pointing toward the collar of the hole. Practically all tunnels are shot electrically and great care must

be taken to place the various delay electric blasting caps in the proper holes, as carelessness in this regard will make the holes fire out of order and result in a poorly pulled round.

It is not standard practice to tamp the holes in tunneling, but the use of stemming is definitely recommended since it tends to prevent the withdrawal of explosives from the holes by preceding shots, improves the fumes, and saves explosive.

In small diameter tunnels requiring 30 holes or less, it is satisfactory to connect the caps in straight series and, if necessary, shoot the round with a blasting machine. With larger rounds, however, a power circuit should be used and the caps must be connected either in straight parallel or in parallel series. In the latter case, the delays of each period and the instantaneous caps are each connected in separate series and the various series connected in parallel. (See Chapter X.) Sufficient time should be allowed to insure that all holes are properly connected, as a missed hole is one of the greatest sources of danger in tunneling. It is strongly recommended that the firing current be brought to the face through a permanent firing line which should be well insulated and installed on the opposite side of the tunnel from all other electric circuits. The precautions detailed in Chapter X for grounding and short circuiting the blasting line should be strictly followed.

SHAFT SINKING

Shaft sinking is always a difficult, hazardous, and costly operation. The greatest difficulty is in getting rid of the water and broken rock. Usually the rock is loaded into a bucket by hand, although in large shafts it may be done with a small mucker that must be lowered down the shaft after each shot. Some work is being done on the development of an orange peel bucket which can be fastened to the end of the hoisting cable and used to excavate a large part of the rock. This will eliminate hand mucking except for the corners and edges. If the shaft makes any appreciable amount of water, it is, of course, necessary to provide suitable pumping equipment so that the water can be handled without delay and with a minimum of interference with the sinking operations. If preliminary borings indicate that large quantities of water may be encountered, the contractor will save considerable time and money by providing grouting equipment. At the first sign of a serious influx of water, sinking operations should be stopped until the flow has been grouted off.

The hazards in shaft sinking lie chiefly in rock or other material dropping down the shaft upon the men working at the bottom. This can be prevented by the use of a bulkhead covering the entire shaft and either located at the ground level or hung from the bottom set of timbers. It should be provided with doors to permit the passage of the bucket and the doors should always be closed when men are in the shaft except when the bucket is passing through the bulkhead. Electric firing should be used to prevent the possibility of men being caught in the shaft by a failure of the hoisting equipment after fuses have been lighted. Finally, only competent, careful, and experienced men should be employed if it is possible to get them. In any event, a maximum proportion of the crew should be experienced and trustworthy. Many men must work together in a small space, usually under a continual drizzle of water and with considerable noise. It is, therefore, imperative that each man understand his duties thoroughly so that the work can go ahead smoothly without confusion or loss of time.

One of the greatest items of expense in shaft sinking is the drilling which normally cannot be carried on until all of the rock from the previous blast has been mucked out. Hammer drills are usually employed as they are much more flexible and rapid than arrangements for mounting the drills on cross bars. The number of drills that can be used depends, of course, upon the size of the shaft. The holes should never bottom less than 1¼ in. in diameter and preferably larger in order to allow the placing of more explosive in the toe of the hole where it is needed. The most economical size of dynamite cartridge for hard rock is usually 1¼ x 8 in. and this will require a hole bottoming from 1⅜ to 1½ in. in diameter. As in the case of tunnels, both the diameter of the shaft and the type of rock govern the number of holes necessary to pull the round.

High strength gelatins such as Du Pont Gelatin and Du Pont Special Gelatin 40, 50, and 60% are usually employed in order to get high loading density, water resistance, and good fumes. Ordinarily it will require more explosive per yard of rock to sink a shaft than it will to drive a tunnel since all of the rock in a shaft round must be lifted and the rock from the preceding holes falls on top of the later firing holes, thus increasing their burden. The advance per round is usually regulated by the mucking cycle rather than by the possible depth which can be pulled in a shaft of any given cross section. It is generally undesirable to break more rock than can be mucked in

one shift. Furthermore, it often happens that a round employing relatively short holes bottoming 2 in. in diameter will require less explosive per cubic yard than a deeper round using a considerably larger number of smaller diameter holes.

SHAFT SINKING METHODS

The rounds used in shaft work are basically the same as those employed in tunneling. Pyramid and V-cuts are commonly used to start the breakage and the directing and drilling of the holes must be carried out with the same degree of care and accuracy. It is good practice to drill the cut holes deeper than the rest of the holes in order to give the round a better chance to break and to form a sump to take care of the water.

Pyramid Cut. Figure 179 shows a round used to sink a circular shaft about 20 ft in diameter. It required an 8-hole pyramid cut, 8 first relievers, 16 second relievers, and 28 trim holes. The cut was primed with instantaneous electric blasting caps, the first and second relievers with first and second delay electric blasting caps respectively, and the trim holes with third delays. The average advance per pound was about 6 ft.

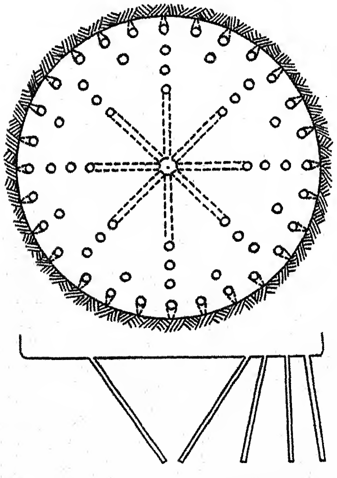


Fig. 179—Pyramid cut in circular shaft

An interesting variation of this round is illustrated in Figure 180. This was a circular shaft 23½ ft in diameter and the 8 holes comprising the pyramid cut were drilled purposely so that the toes were about 2½ ft apart. Each cut hole was loaded with 2 separate charges, the bottom one being primed with first delay electric blasting caps, and the top one with instantaneous electric blasting caps. 2 ft of sand stemming was placed on top of the lower charge before loading the upper one.

The 8 first relievers were primed with second delays and the 28 trim holes with third delays. When the current was applied, the upper charge in the cut took out the top portion

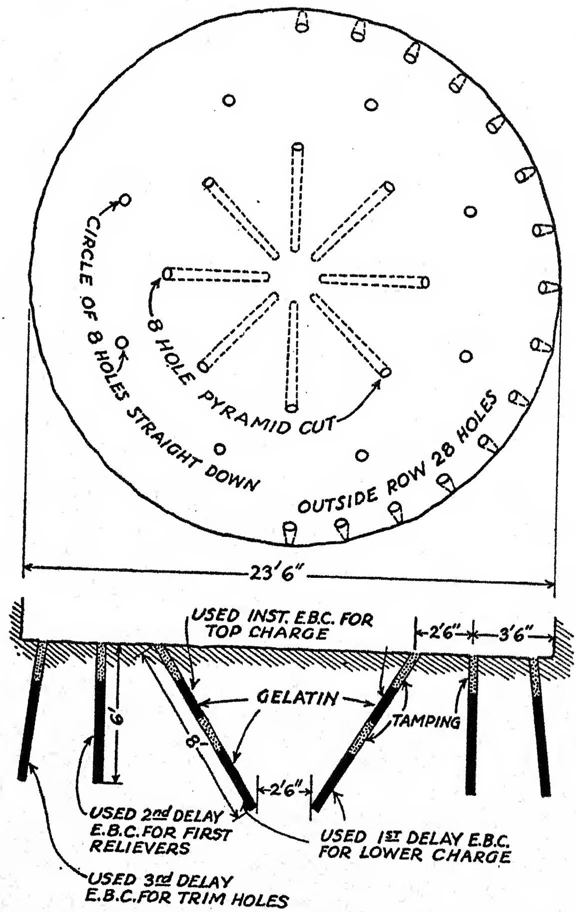


Fig. 180—Double primed pyramid cut in circular shaft

making it much easier for the bottom charge to pull clean. This method saved some drilling, consistently pulled the cut, and produced an average advance of about 6 ft per round.

V or Wedge Cut. Rectangular shafts are commonly sunk with the V-cut as in Figure 181. This round was used in a 10- by 20-ft shaft and is practically the same as would be used for a tunnel of the same size except that no attempt was made to pull more than 6 ft per round. The holes marked "x" were primed with instantaneous electric blasting caps and those marked 1, 2, 3, etc., with the corresponding periods of delays.

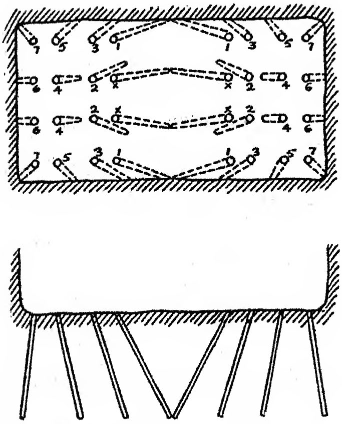


Fig. 181—Shaft round using V-cut

Ordinarily, when a V-cut is used, the entire round is drilled and shot at once, but in very large shafts, it is sometimes advantageous to shoot the cut in one end and muck this broken rock out first. Flat, steel sheets are then laid on the bottom of this sump and the rock in the other end of the shaft is shot onto them. The smooth, flat bottom provided by the steel makes it much easier to shovel the broken rock. This method is illustrated in Figure 182.

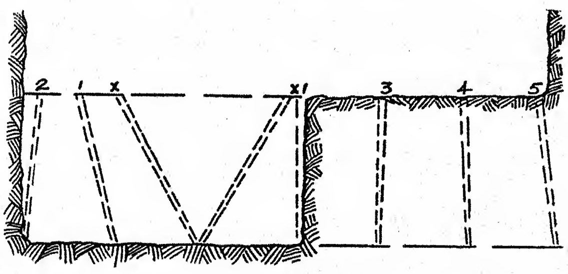


Fig. 182—Round for very large shafts with cut at one end

Large Drill Hole Cut. Figure 183 shows a new method of sinking that is gradually finding favor in large shafts. A large diameter well drill or calyx drill hole is put down in the center and used as the cut or free space into which the first relievers break. Additional holes are drilled as needed to fill out the round. Note that all holes are pointed straight down or parallel to the axis of the shaft similar to the relievers shown in the "burn" cut round described in Chapter XII.

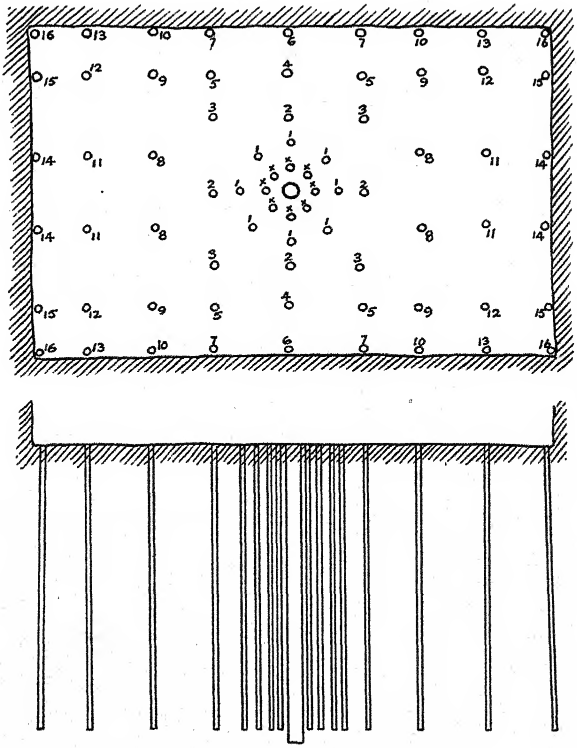


Fig. 183—Shaft round using large diameter drill hole as a cut

In the round illustrated, the shaft was 13 by 21 ft and the center hole was 5 in. in diameter at the top, bottoming at 3½ in. at a depth of 12 ft. The other holes were drilled 11½ ft deep and the average advance was about 11 ft per round. The numbers shown by the holes indicate the order of firing.

A variation of this method involved the drilling of a 6- or 9-in. diameter well drill hole 50 to 60 ft deep in the center of the shaft and filling it with sand. After drilling the rest of the round, the sand is pumped out to the desired depth of the round and the smaller diameter holes loaded and fired as usual. In some instances, a 36-in. calyx drill has been used with the large hole intercepting a tunnel or drift at the shaft bottom. The large hole was used as a mucking chute.

Sumping Cut. Figure 184 shows the sumping cut for shaft sinking as applied to large shafts. It is so called because each round forms a sump to collect water so that it can be pumped

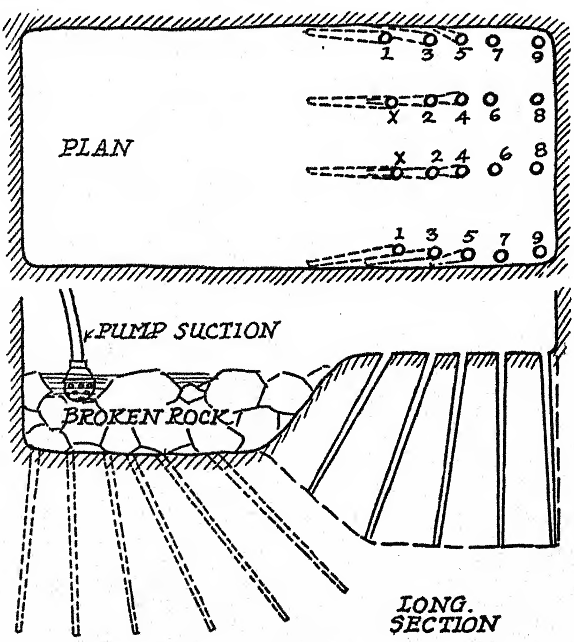


Fig. 184—Sumping cut for large shaft

out easily and leave a fairly dry bench for drilling. This round is especially useful where the rock is of such a nature that water causes the broken rock to settle or pack, making it very difficult to dig to the bottom of the muck pile. With this cut, it is not necessary to clean all the rock out of the lower end of the shaft after each round. This method was used very successfully in a shaft sunk for the Cascade Tunnel in the State of Washington.

Loading, Tamping, and Firing. Most shaft work is wet, so gelatin dynamite is ordinarily required, but in instances where the water conditions are not severe, "Gelex" No. 1 or No. 2 may prove more economical. The cartridges should be slit, loaded one at a time, and pressed firmly into place with a wooden tamping stick. The primer should be the second cartridge loaded into the hole to prevent cut offs, and except where all holes are full of water, they should always be tamped to the collar with good clay or sand stemming.

All shaft rounds should be fired electrically so that the entire crew can be out of the shaft before the switch is thrown. Great care must be exercised to see that the delays are properly loaded so that all holes will fire in the desired order.

While small shafts requiring 30 holes or less per round can usually be fired with a blasting machine using a straight series connection, it is generally more satisfactory to use a power circuit and connect the caps in either straight parallel or parallel series. Connections in shaft work are likely to get wet and if series connections are used, some holes may be shorted out, causing a poorly pulled round, loss of time, and possibly a serious accident. This trouble can be largely eliminated by using the straight parallel connection and firing with the power circuit. When the work is not too wet, the parallel series hook-up may be used, connecting all instantaneous caps in one series, all first delays in another, all second delays in a third, and so on, finally connecting all these series in parallel.

CHAPTER XVIII

SUBMARINE BLASTING

Under-water work of all sorts requires more care and experience than similar work above water. It is usually impossible to see what is being done and conditions under which drilling, loading, and firing of charges are carried out are not too satisfactory. Since the pressure is greater on all sides than in the open air, the work to be performed by the explosive is increased, which necessitates deeper sub-drilling, closer spacing, and higher loading factors. Furthermore it is usually essential that the blasting be properly done the first time since reshooting is generally impractical.

HARBOR AND CHANNEL WORK

Deepening Harbors and Channels. In rock or very hard compacted sand or clay, this deepening process is very tedious and difficult. It calls for expensive machinery and outfits in the way of drill boats, dredges, and barges.

In some cases, charges of explosives placed on the surface of the hard material will shatter it in somewhat the same manner as mudcapping boulders. This is not an economical method of using explosives.

Cofferdams and caissons are sometimes employed in draining the area, and then the material is drilled and blasted in the usual manner. This is quite expensive and only feasible for comparatively small areas, but is practical in foundation work of all kinds under water.

The usual method is to erect platforms supported on spuds and anchored so as to prevent movement in the water and to do the drilling and loading from the platform.

For extended work of this kind, a scow or boat upon which the drilling equipment is mounted is anchored and steadied by means of spuds resting upon the bottom. Each boat carries from one to six or more large piston drills or well drills operated by steam or compressed air, mounted on standards somewhat like pile drivers along the side of the boat. The standards can be moved sideways by means of tracks and the drills raised and lowered in the standards.

The boreholes are usually from 2½ to 4½ in. in diameter,

or when well drills are used 5 to 6 in. and where sand, gravel or other material lies above the rock a weighted pipe of sufficient diameter to accommodate the drill bit with a cone-shaped header above the water surface is used. This serves as a guide in starting the hole and sinks down to the rock surface, thus keeping loose debris out of the borehole.

The most important point in submarine blasting is to drill the holes to the proper depth below grade. One rule is to have the bottoms of the boreholes the same distance below grade as the spaces between the holes. A number of contractors who specialize on submarine work drill all holes 10 ft below grade irrespective of the depth of the cut to be made. The holes must be spaced much closer together than for blasting in the open on account of the water pressure. The maximum spacing recommended is on 10-ft centers. This, with all holes 10 ft below grade, will generally insure good results.

For many years the explosives used in submarine blasting were either Submarine Dynamite (60% Straight Dynamite) or Du Pont Gelatins of 60% or higher grade strength. When the straight gelatins are used, many contractors use a primer of 60% Straight Dynamite to assure complete detonation. When either Submarine Dynamite or gelatin primed with Straight Dynamite is employed, propagation from hole to hole usually takes place. In recent years particularly, there has been much agitation against propagation and in certain government work this type of blasting is prohibited. Under these circumstances, Du Pont "Hi-Velocity" Gelatin is best adapted for submarine work. In fact, "Hi-Velocity" Gelatin has numerous advantages other than the fact that it is less likely to propagate.

For hard rock under considerable depths of water, 70 or 80% "Hi-Velocity" Gelatin or the corresponding grades of Du Pont Gelatin are recommended, while for stratified limestone, shale, or softer rocks, the 60% strength is satisfactory. The quantity of explosive necessary depends upon the depth of the water, hardness of the material, and depth of the boreholes. As a rule, from 1 to 5 lb of dynamite are required per cubic yard of pay rock, the smaller amount being used in softer rocks and shallow water.

Waterproof electric blasting caps should be used for all submarine blasting. In ocean waters of considerable depth, two caps per hole are frequently used.

The loading as a rule is done by means of a metal tube called a "submarine charger." This consists of a length of boiler tubing from 4 to 10 ft long of proper diameter to slide

easily to the bottom of the hole. The bottom of the charger section has a longitudinal slit about 18 in. long and ⅜ in. wide on one side, to allow wires of electric blasting cap to slide through easily. To the upper end of the loading section is welded a pipe of smaller diameter and length to reach from the bottom of the deepest hole to a level of the drill boat deck. Inside this upper section is a tamping stick or 1-in. pipe to the bottom of which is attached a wooden piston or tamper. This inner or tamping pipe is equal to or greater in length than the outer tube.

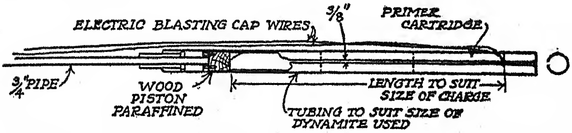


Fig. 185—Section of loading tube for loading holes under water

The dynamite cartridges, of proper size to slide easily into the charging tube, are pushed up into the tube from the bottom in the same manner as loading a borehole. The cartridge containing the electric blasting cap is loaded into the tube last, the wires being carried out through the slit. When the blaster lowers the tube into the hole he holds the electric blasting cap wires in his hand in order to prevent the cartridges from dropping out. When the load in the tube is heavy, the cartridges are often held up in the tube by inserting wooden chimes or wedges at the bottom of the tube. The tube is then lowered to the bottom of the hole. The tamping section is loosened and dynamite cartridges pushed down while the outer pipe is pulled up. For loading in this manner, it is well to have the dynamite packed in heavy paper shells known as "submarine packing."

Another method often used in deep water is to load the explosive into metal shells such as leader pipe or stove pipe. The wrappers are removed from the dynamite cartridges and they are packed into the shell on the deck with the primer usually about in the middle of the charge. These shells may be of different lengths according to depth of hole. The shell is lowered to the bottom of the hole and the wires attached to the outrigger until final connections are made. There should be no bare joints of the electric wiring touching the water or the steel deck of the drill boat for this is likely to cause misfires. A little extra taping at this point is good practice.

Cutting Off Piling. When it is desired to remove wooden piles used for bridges, wharves, and other purposes, they are most easily cut off well below water line by using Submarine Dynamite detonated with electric blasting caps. The cartridges are tied together end to end, strung around the pile, lowered to the point where it is desired to cut, and then fired.

When piles are sunk in clusters or clumps, commonly called dolphins, it is usually better practice and economy to cut each one off separately by blasting than to attempt to cut the entire dolphin at one blast.

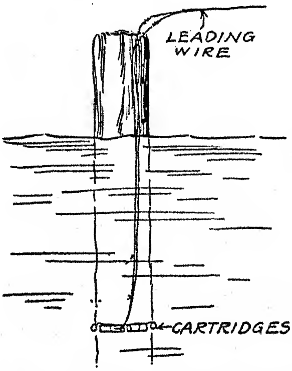


Fig. 186—Method of cutting off piles by stringing cartridges of dynamite around them

Sunken Logs and Stumps. In blasting out logs and stumps which have sunk in channels and rivers, thus making navigation dangerous, the general directions apply as for other under-water work. Where the charges must remain under water for some time "Hi-Velocity" Gelatin 50 and 60% should be used. The charges should always be fired by electricity. The size of charges varies from 5 to 50 lb, depending upon the size of the stump or log, and the depth of water. They should be placed under the center and immediately against the obstruction when possible. Frequently several charges placed at intervals are necessary in blasting out and breaking up long logs or sunken trees.

BLASTING WRECKED SHIPS

The necessity frequently arises for the removal of sunken ships, barges, boats, and other vessels which have become a menace to navigation. Dynamite is the quickest and most effective agent for breaking up these dangerous obstructions and ridding the channels of them.

Owing to the generally unfavorable conditions and difficulties under which the work must be prosecuted, the most propitious time must be selected and the work speedily done. Such varying elements enter into a consideration of this sub-

ject that specific directions cannot be given. The height of tide, direction and velocity of wind, height of waves, character of bottom, age of wreck, kind of material in hull, and character of cargo must be considered.

A thorough investigation by divers should be undertaken to ascertain the depth of water, how the wreck lies on the bottom, whether or not it is covered with sand or mud, the feasibility of getting inside the hull, and the most advantageous points for the location of the charges of dynamite.

In some instances it is necessary to fire charges at different places around the hull to blast away the sand before an examination can be made. Again, in many cases, holes large enough to permit the entrance of the diver must be blown in the hull at different points to assist in placing the large charges of explosives in the best location. These preliminary charges may be comparatively small, usually from 25 to 200 lb being ample, depending upon the amount of work to be done at each point. It is sometimes necessary to cut or shear off some of the more important bracing beams, plates, and angles. This can be done by stringing the cartridges end to end around the beam or along the plate at the point desired. The cargo, such as coal, for instance, will sometimes prevent the placing of the charges of explosives at the most logical points, and it may be necessary to blast large holes in the bow and stern or along the sides and wait until the action of the water currents has cleared some of the cargo from the hold before proceeding further with the work.

Generally the best results in breaking up wrecks have been obtained by placing large charges inside the hull. The amount to use depends upon the depth of water, character of material in the hull, whether steel or wood, whether or not it is buried in sand and mud, and the size of the vessel. For small hulls, one large charge of from 300 to 1,000 lb placed amidships is usually sufficient. Slightly larger vessels will require larger charges, and large steel hulls will frequently require several charges of from 1,000 to 2,000 lb each, one charge being placed forward, one amidships, and one aft, the whole being fired simultaneously. Where it is impossible to put the charges inside the hull, they should be somewhat larger and spaced at closer intervals and should be placed as far under as possible and directly against the hull.

The explosives recommended for this work are 60%, 75%, and 80% Du Pont Gelatin with small quantities of 60%

Du Pont Straight for primers or Du Pont "Hi-Velocity" Gelatin packed in extra heavy waterproof submarine packing. The cases of gelatin should be stacked closely together, as more complete detonation is secured than where attempts are made to have the exploding wave propagated from one case to another placed at short intervals.

The charges are primed by replacing 5 or 6 cartridges of gelatin from one case with the same number of cartridges of 60% Straight Dynamite, one of which should contain the waterproof electric blasting cap, well taped and sealed in, to prevent the entrance of water. If "Hi-Velocity" Gelatin is used, a straight dynamite primer is unnecessary. The wires from the cap should be carried out through a small notch cut in the case and the case cover nailed back on. This primed case should be lowered into place by a strong wire or rope and a buoy attached to the top end of the rope. The electric blasting cap wires should be attached to the buoy, but all strain and pulling of the buoy should be carried by the rope or heavy wire and not by the small electric cap wires. Where the tide or undercurrent is strong, it is recommended that electric blasting caps with very short leads be used and that No. 14 leading wires be spliced to them and carried from the charge to the buoys in order to make a stronger connection.

The detonator wires are connected in series and to the leading wires, all joints being well taped. Then as the firing boat drops back, the wires are payed out carefully until a distance of 500 to 1,000 ft is reached. The blast is fired by means of a blasting machine of ample capacity.

Where the charges are to be left under water for some time, the primers should be sealed up in a waterproof tin or lead cylinder. In this class of work it is much better practice to have two or more primers in each charge as a safeguard against the possibility that the wires of one electric blasting cap will become broken or short-circuited, resulting in delays and sometimes in loss of the charge.

It is frequently desirable to shear off sections of steel plates, angles, and braces so that as much as possible of the plates can be salvaged undamaged. This can be accomplished by stringing the dynamite cartridges end to end along the plate or around the brace. Du Pont Submarine Dynamite or 60% "Hi-Velocity" Gelatin is usually suitable for this work, but if the steel is very heavy, it may be advisable to use Blasting Gelatin. Two detonators should be placed in each charge.

CHAPTER XIX

AGRICULTURAL BLASTING

Explosives have a very definite place in agriculture, just as they have in mining, quarrying and construction work. They represent a source of power to do the heavy work of clearing, draining, and maintaining land. In such work explosives are economical because of the great amount of time, labor, investment in machinery and maintenance which they save. In this chapter some of the more common uses of explosives in agriculture are described.

STUMP BLASTING

Stumps take up room in the field and reduce yields; prohibit the use of improved machinery and increase the cost of cultivation; break and destroy tillage equipment; harbor vermin, plant diseases, and weeds; are unsightly and detract from the value of a farm.

To remove the stumps from a large area where most of them are big and have heavy brace roots, a combination of blasting and pulling is suggested, using dynamite for removing the stumps easily blasted and for splitting the large ones, then pulling the fragments by means of a puller, tractor or donkey engine.

The exclusive use of dynamite is recommended when the stumps are scattered, or where there is but a little work to do, because even though more dynamite is required, it costs much less than buying expensive equipment and moving it so often.

Where there are any gullies, dispose of stump fragments by throwing them into the bottoms where they will help catch the silt and sand, and where they will act as blind drains when the gullies are finally filled.

Fat pine stumps are often sold to companies interested in wood distillation, when the distance to the plant is not too great. By selling the wood, such stumps can usually be disposed of for enough to pay the cost of clearing the land. They can sometimes also be sold to homes for firewood or kindling at good prices.

General Principles. Different classes of stumps have very different roots. Some have heavy tap roots, others only lateral, spreading roots, while some have both kinds. The loading must suit the nature of the roots, and be placed to break their hold in the soil.

A green stump has a large mass of small tendril roots so interwoven with the soil that it naturally requires a relatively heavy charge of dynamite to dislodge it. Furthermore, the removal of a green stump leaves a larger hole to fill, and the pieces of the blasted stumps still retain much of the earth held by the small roots which makes its destruction by burning a slow process. It takes from three to seven years for the small roots of a freshly cut tree to die and decay, depending upon the type of wood, the amount of moisture in the ground, and the climate. Obviously whenever the removal of a stump can be delayed until these small roots have rotted, the stump can be taken out with considerably less dynamite. In clearing land for cultivation, this is generally taken into consideration so that it is safe to say that five hundred dead stumps are blasted for every green one. However, there are occasions, as in ditching through woods or clearing the right of way for road build ing, when blasting green stumps is desirable.

Stumps are easier to blast out of firm soils than out of loose sandy soils, and allowance for this must be made in placing the charges.

The charge is loaded at the bottom of the hole, and the explosive breaks out through most soils in such a way as to form an inverted cone, the top of which is a little less than twice the depth of the hole. The charge should be deep enough to make the cone include all of the stump and part of the main roots, and heavy enough to split the stump, loosen the roots from the earth and turn the pieces back around the hole so that they can be easily removed.

It is important that the boreholes should be of large enough diameter to permit massing the explosive at the bottom of the hole instead of stringing it out along the stem. See Chapter VII for methods of making boreholes in earth and in wood.

If the holes are dry, slit the cartridges and pack them solidly in the bottom of the hole. If the holes are wet, try not to break the paper shell, so as to guard as far as possible against injury to the dynamite from water, and fire soon after loading. If the water covers the charges to a depth of a foot or more, no other stemming is needed.

When the charge consists of several cartridges, place the primer last or next to the last cartridge toward the top of the hole, with the blasting cap or electric blasting cap pointing toward the main part of the charge. Tamp the remainder of the hole with earth tight to the mouth.

In firing, the same care as to safety of the blaster and all spectators should be observed as noted in Chapter X.

The explosives recommended for blasting stumps are: "Agritol" No. 2 or "Red Cross Extra" 20% for heavy, firm soils or in wet soils that offer good resistance; "Agritol" No. 2, in larger charges, or "Red Cross Extra" 30% in lighter soils; and "Red Cross Extra" 40% in loose sandy soils where quicker action is necessary. "Agritol" is recommended for dead stumps only.

Blasting Tap-Rooted Stumps. There are two methods of loading tap-rooted stumps:

(1) With a wood auger, bore a hole diagonally downward and a little more than half way through the tap root, pack the charge into the hole and tamp well. (Figure 187.)

The amount of charge depends upon the diameter of the tap root and size of the stump. If the stump is large and heavy, it may be desirable to spring the hole so that a larger charge of explosive can be packed into the bottom of the hole. (Figure 188.)

(2) Bore or punch two or more holes into the earth immediately alongside of the tap root or dig away the earth with a spade, as in Figure 189.

The charges should be spaced equally around the root and put down to a sufficient depth to break off and lift out the stump and roots. The charges must be fired together with electric blasting caps.

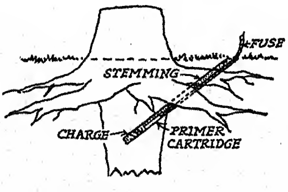


Fig. 187—When a stump has tap and spreading roots the charge should be placed in the tap root and should occupy all of the hole made in the tap root

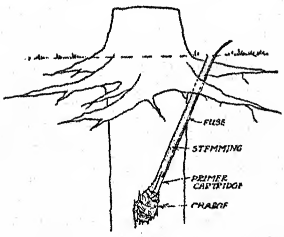


Fig. 188—Loading a large tap-rooted stump in a hole bored in the root and then sprung

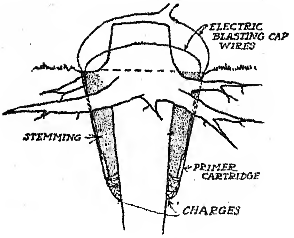


Fig. 189 — Loading a tap-rooted stump in holes dug alongside the root

The first method requires more labor, while the second method requires more explosives. The first method, because it splits the wood up better, is preferable when the fragments are to be used for fuel or distillation, but the second method is better where the brace roots are very heavy, or it is desirable to get out all of the tap root.

"Agritol" or "Red Cross Extra" 20%, or, if the soil is light, "Red Cross Extra" 40% are the explosives recommended.

Blasting Lateral-Rooted Stumps. To blast a small oak or similar lateral-rooted stump out of a sandy soil, punch a hole diagonally under the main part of the stump to a depth of not less than 3 to 3½ ft and load with "Agritol" No. 2 or "Red Cross Extra" 20%. (Figure 190.) In firm clay soil, the hole may be shallower.

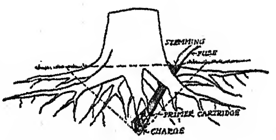


Fig. 190—In loading a small lateral-rooted stump the charge should be kept well down

A large oak or other lateral-rooted stump may be blasted from a firm soil by placing a hole diagonally under the main part of the stump, as has been described for small stumps, and springing this hole so that it will contain a sufficiently large charge of explosives, or by placing one hole under the center and other holes under the heavy brace roots, distributing the charge among these holes and firing them all together with electric blasting caps. (Figure 191.)

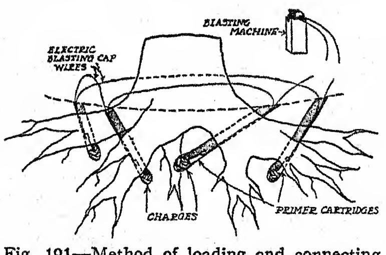


Fig. 191—Method of loading and connecting charges for blasting a large lateral-rooted stump

For either method, the explosive may be "Agritol"

No. 2 or 20% "Red Cross Extra." In case of green, lateral-rooted stumps, the explosive recommended is 40% "Red Cross Extra."

Large hollow stumps generally need two or more charges under the solid parts of the stump, and it is often advisable to tamp the hollow full of soil. Small hollow stumps can be blasted by punching a single deep hole through the hollow, loading and tamping tightly both the borehole and the hollow.

BOULDER AND LEDGE BLASTING

Boulders offer the same troubles as stumps in fields, roads, and in construction work. Blasting with dynamite is the quickest and easiest method of disposing of boulders. There are three methods of loading: (1) Blockholing, (2) Snakeholing and (3) Mudcapping.

Blockholing. Blockholing consists of drilling a hole into the boulder and charging it with a small amount of dynamite. It is the best method for breaking very hard or very large boulders, especially those of the "nigger-head" type that are difficult to break by other methods. The hole should usually be drilled about half way through the boulder and may be an inch or larger in diameter (Figure 192).

The explosive is sometimes removed from the shell and packed firmly into the bottom of the hole. When the entire charge is in, make a hole for the cap in the top of the powder with a pointed hardwood stick. Press the cap into the hole and tamp it in with moist soil. Tamping the hole helps the explosive to give the best breakage, and with cap and fuse blasting, it is a necessary safety precaution. Accidents have occurred from premature explosions caused by burning fuse curling around so as to spit fire directly on the charge in an untamped borehole.

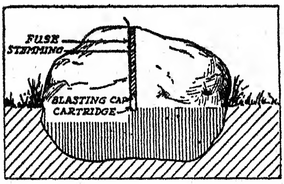


Fig. 192—For shattering a large boulder by the blockhole method the hole is drilled about halfway through the boulder, carefully loaded, and tightly tamped

As the confinement is perfect in the proper loading, any of the du Pont high explosives recommended in this book will give good results. "Agritol" and "Red Cross Extra" 20% are especially recommended.

Blockholing is very effective in blasting outcropping ledges

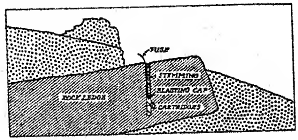


Fig. 193—Correct method of loading the outcrop of a rock ledge

that are too large to remove entirely. (Figure 193.)

A good tool for examining the size and location of submerged boulders can be fashioned from quarter inch iron rod (Figure 194). The sharpened end is punched into the ground.

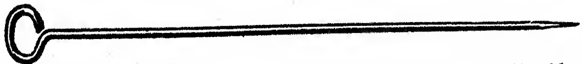


Fig. 194—Sounding rod for examining the size and location of buried boulders

Boulder fragments can be most easily loaded on sleds or stone boats. For long hauls, wagons or carts should be used. Boulder fragments make excellent material for roads, fences, stone for concrete and filling for gully bottoms.

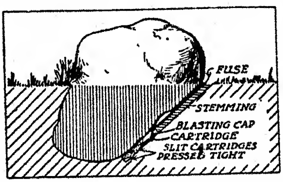


Fig. 195—Proper method of placing and loading a charge near a boulder for breaking or moving it with a snakehole shot

Snakeholing. Snakeholing consists of punching a hole under but immediately against the bottom of a boulder and placing the charge of explosives in as compact a shape as the size of the hole will permit. A better idea of the method can be had by studying Figure 195. The explosive, being confined on the underside by the earth, can exert a powerful blow on the boulder and will roll it out, or if a sufficient charge is used will break it in fragments.

This is one of the easiest and most successful methods of boulder blasting. The best explosive for this work is either "Red Cross Extra" 40% or Du Pont "Extra" D. "Agritol" and "Red Cross Extra" 20% are good where the soil is heavy and offers enough resistance. Electric blasting is not generally used unless the boulders are very large and more than one charge is needed to blow them out. Some blasters prefer to roll boulders out with a snakehole shot and later break them with a mudcap.

Frequently a combination of a mudcap or even several mudcaps with one or more snakeholes is most effective.

Mudcapping. Mudcapping is known by a variety of names, such as "bulldozing," "blistering," "poulticing," "plastering," and "dobying." It is made possible by the fast, shattering action of the higher strengths of dynamite. One method of mudcapping consists of removing the dynamite from the shell and packing it in a compact conical heap on the boulder, and, after inserting a cap and fuse, covering it with several inches of thick, heavy mud. Where there is a great deal of this work to be done, the explosive is not removed from the wrapper, but whole or half cartridges, sometimes slit, are arranged as compactly as possible at a given point on the boulder. The cap is inserted in the end of one of the cartridges, and the whole charge covered with mud. (Figure 196.)

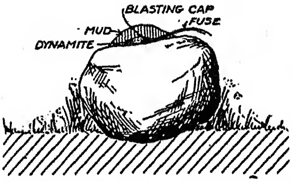


Fig. 196—A correctly placed mud-cap, showing mud several inches thick

The explosive should be placed on the boulder at the place where the rock would be struck with a hammer were it possible to break it in that way. This may be on the top or the side. If the boulder is embedded in the ground, a snakehole shot to roll it out on the surface should first be made, because the confining dirt makes it much harder to break with a mudcap shot. The mud covering should be as thick as it is convenient to make it, not less than 5 or 6 in., and free from stones, as the blast will throw them as though they were bullets. Never lay a stone on top of the mud, for the same reason.

The explosives used are "Red Cross Extra" 40% or Du Pont "Extra" D.

TABLE XV

Charges for Boulder Blasting

Diameter of boulder in feet	Approximate number of cartridges, 1¼"x 8"—in average hard stone—required for:		
	Mudcapping	Snakeholing	Blockholing
1½	2	1	¼
2	3	1	¼
3	4	1½	½
4	7	4	¾
5	12	6	1

BLASTING DITCHES AND PONDS

Ditch blasting is effective for digging open ditches in many kinds of ground; it is not effective in loose sand or gravel or in hard packed dry earth.

In size, blasted ditches vary from about 2½ to 12 ft in depth and from 4 to 40 ft in width, depending on the method of loading and the quantity of explosive used.

There are two distinct methods of blasting ditches: the propagation method and the electric method. The propagation method can be used only in wet soils, while the electric method can be used in either wet or dry soils. The explosives and blasting supplies needed and the methods of loading vary considerably in the two methods.

Among the most striking advantages of ditching with dynamite, as compared to other methods, is the reduction in cost, the absence of a large soil pile along the ditch, the little time required, the absence of overhead expenses for equipment, the ability to dig successfully where the conditions are too difficult for other methods, the ability to dig both large and small ditches, and the simplicity of the methods.

Ditching by the Propagation Method. In wet soils, the quickest and generally the most economical method of ditching is the propagation method with Du Pont Ditching Dynamite. In this method only the hole at the open end is primed, the concussion from the explosion of this being sufficient to propagate the detonation through the wet earth and set off the whole line of charges. The end hole may be primed with either a blasting cap and fuse or an electric blasting cap. Only a straight dynamite can be used for the propagation method, as other kinds are too insensitive to be detonated by the shock from a single primer in a central hole. This method can be practiced in the roughest of swamps, even where the surface is covered with the heaviest of swamp stumps and several inches of water.

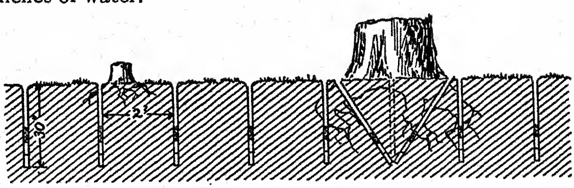


Fig. 197—Line of holes loaded for propagation ditch blast in wet soil with increased charges used under large stumps

The simplicity of the propagation method and the excellent results obtained must be seen to be fully realized.

The course of the ditch having been decided on by a survey or close study of the slope, as indicated by the surface drainage, and the trees having been chopped from the right of way, the work may be begun.

The first thing to do is to make a few trial shots to ascertain the best depth and spacing for the holes. For ditches up to 3 to 3½ ft deep the depth of boreholes will usually be about 24 to 30 in., and the spacing between the holes from 18 to 24 in., although it may be necessary to increase the depth and decrease the spacing in some cases. It is well to begin the test with holes 2 ft deep and 18 in. apart. Keep these in line and load about 10 of them with one cartridge each. If a little water covers the cartridges in the holes, no further stemming will be needed. If not, tamp well with earth. One hole is charged with an extra primer cartridge, and it is also well to put one additional cartridge in each hole adjoining the primer.

This loading should lift the soil at least 200 ft into the air, scatter it over the adjoining area for a distance of 150 ft and leave a good, clean ditch. If it does not, try a different loading. It may be necessary to make the holes deeper in some soils and not so deep in others. Usually in swamp soils the ditch made is a foot or two feet deeper than the charge, but sometimes it is necessary to load to the full depth.

If the test shot makes too large a ditch, the spacing can be increased a little, but should seldom be greater than 24 in., and then only in warm soil. For very small ditches, less than a full cartridge of explosive may be used in each hole.

Small ditches (for instance, about 2 ft deep and 4 ft wide) in soils where there is little trouble from roots can be dug with half cartridge charges, but when using such small loads the spacing between holes can seldom be over 18 or 20 in.

Larger ditches can be dug by using two or more cartridges in each hole, and a second, or even a third, line of holes may be put down about 4 to 5 ft from the original line and loaded in the same way. When two or three lines of holes are used, it will be necessary to prime the center hole in each line with an electric blasting cap and connect these in one series, or to put in one or two extra charges between the rows to insure the simultaneous detonation of all the charges.

Ordinarily in swamp soils the boreholes can be put down with little effort. If the soil is at all hard, or has a heavy crust, the fastest tool is a good sharp crowbar or punch, but if soft

and mucky, a heavy tamping stick will suffice. The holes should not be left open, but should be loaded at once, otherwise they will cave in or be filled with floating slime.

Ditching by the Electric Method. In the electric method of ditching each hole is primed with an electric blasting cap. While it is possible to blast ditches only in wet soils by the propagation method, that is, exploding a whole line of charges by the detonation of a primer in the center hole, the electric method can be employed in any class of material, except dry sand, in which it is practically impossible to blast ditches.

An ammonia dynamite can be used for ditching by the electric method but the higher velocity of detonation of a straight dynamite gives a cleaner, more uniform ditch. Consequently, Du Pont Ditching Dynamite is recommended for this method of ditching as well as for the propagation method.

The layout of the ditch is exactly the same as for the propagation method, but as each hole is primed it is possible to space them farther apart in the row. The normal distances are from 24 to 32 in. for small ditches, and up to 48 and 52 in. for large ditches. After three or four trial shots similar to those described for wet ditching have established the proper depth and spacing of the holes, and the amount of dynamite per hole, the blaster is ready to begin actual operations. The holes may be put down with a subsoil punch, crowbar, soil auger or any other tool suitable for the particular class of soil.

Unless water covers all charges they should be thoroughly tamped. It is best to punch only enough holes for one blast, load them and fire, before putting down more, as they are likely to be filled up or covered with trash thrown up by the blast.

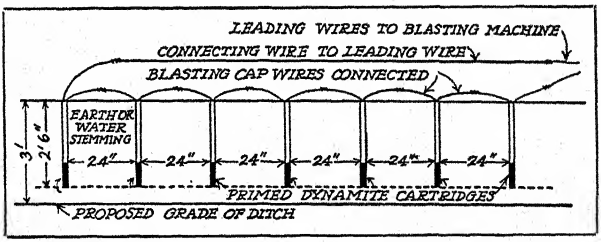
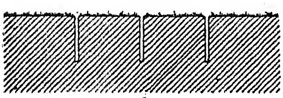


Fig. 198—Line of holes loaded for an electrically fired ditch blast

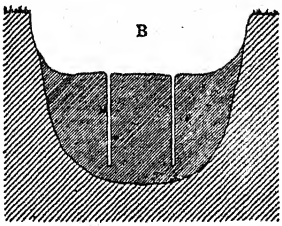
When only one cartridge is used in a hole it must contain the electric blasting cap, and should be pressed well down to the bottom of the hole and tamped so that there is no air space left to reduce the effect of the blast. When several cartridges are used in each hole, the primer should be on top, with the cap pointing downward.

As the work progresses, the soil should be carefully watched, and any needed variation made in the loading so that it may always conform to the material to be lifted.

When a larger ditch is desired, the loading may be in deeper holes, using more explosive or a higher strength of explosive; or two or more parallel lines of holes may be employed, especially where a wide but shallow ditch is needed. Where a very deep ditch is needed, blast a wide, shallow ditch with two or three parallel rows of holes (Figure 199-A) and then



A



B

Fig. 199—Detail of blasting a ditch with two shots; for large deep ditches shallow loading as shown in (A) is used to dig a wide shallow ditch, and then another set of holes (B) is loaded and fired

load one or two rows in the bottom of the shallow ditch (Figure 199-B) thus blasting another ditch in the bottom of the first one. This latter method has been very efficient in opening large ditches 8 or 9 ft deep through heavy bottom lands for the correction of stream channels.

When stumps or boulders are encountered, heavier loading is needed. This should be in keeping with recommendations made elsewhere in the book.

Dynamite is now being used successfully for the removal of mud and debris from "earth tanks" or water holes.

Wide Ditches and Ponds. The cross-section method (Figure 200) is applied to ponds up to 40 ft wide—the width being the governing factor and not the length. This method is used when the material to be removed is up to 3½ ft in depth.

The relief method (Figure 201) requires three separate blasts for the removal of 3½ to 5 ft of mud, and where the width

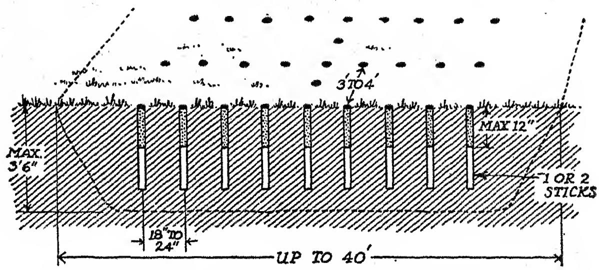


Fig. 200—The cross-section method of loading dynamite

does not exceed 30 ft. The No. 1 row of holes is shot by the propagation method.

Following this, row No. 2 is shot in like manner. This makes two ditches whose outside edges should be approximately 30 ft apart. The center row of holes is then loaded, using about twice

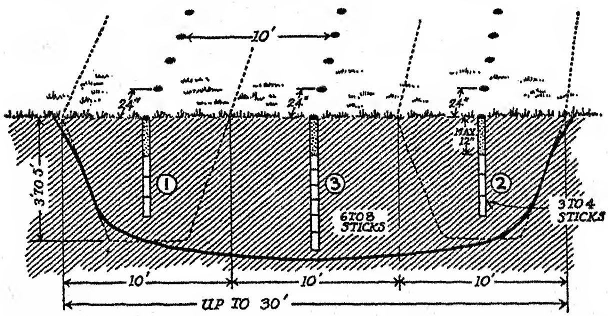


Fig. 201—The relief method of loading dynamite

as much dynamite per hole as in Nos. 1 and 2 rows. The two outside ditches act as a relief, allowing the material in the center to be more readily distributed to either side. This relief method works best when the pond is nearly dry. However, if there is sufficient water to fill, or partially fill, one of the relief ditches, better results are obtained if the two relief ditches are connected across one end, in order to distribute evenly the accumulated water.

The third method (Figure 202) is known as the post-hole method. A single row of holes, usually made with a post-hole digger, is put down on 4-, 5- or 6-ft centers. Holes are loaded up to 25 lb per hole. The charges are shot with an electric blasting cap in each hole. If the ground is wet, one electric blasting cap placed in the center hole, when exploded, will set off all the other charges by propagation.

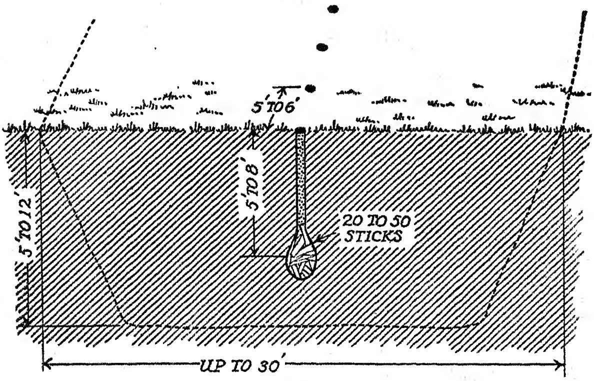


Fig. 202—The post-hole method of loading dynamite

The amount of dynamite required in each hole is very dependent upon the kind of soil and the amount of moisture in the soil.

Using the cross-section method (Figure 200) one (1¼"x 8") stick of Du Pont Ditching Dynamite per hole should remove from 2 to 2½ ft of material—two sticks per hole should remove approximately 3½ ft of material.

In the relief method (Figure 201) three to four (1¼"x 8") sticks of Du Pont Ditching Dynamite per hole in rows 1 and 2, and six to eight sticks per hole in row 3 should give 5 ft of depth.

If longer ditches or larger charges are required, multiply the above figures by two, three, or four, according to the number of rows, distance, or charges required.

In case of doubt as to proper distance between holes or rows, or depth and strength of charges, try several 10-hole test blasts, with different charges at different distances and depths. All cartridges should be 1¼"x 8".

In post-hole work (Figure 202), it is recommended that at least twenty sticks of Du Pont Ditching Dynamite be loaded in each hole.

There is no limit to the length of pond that may be blasted, but it is quite difficult to blast ponds wider than about 30 to 40 ft, as the earth falls back into the hole. For all sizes and kinds of ponds, dynamite can best be used for loosening up and blowing out a part of the soil. The rest can be taken out with scrapers. For blowing the soil out entirely, the methods of loading are the same as for ditch blasting.

Excellent results in loosening medium-hard ground for scrapers have been obtained by following methods similar to those described later in this chapter under "Subsoil Blasting." A slow acting explosive such as 20% "Red Cross Extra" works best. The loading should be slightly heavier than for subsoiling and the holes much closer together—from 4 to 6 ft, depending on the soil.

Straightening Streams. The crookedness of the banks of a stream and the vegetation and sediment in the bottom have a direct bearing on the amount of water carried away by the stream. A crooked alignment retards the stream flow from 30 to 60%. In many instances straightening out a stream has doubled its capacity for disposing of run-off water.

The size of the stream governs the method of blasting. Where small ditches are necessary, these can be blasted satisfactorily by loading one to three sticks of dynamite in a row of holes 18 in. apart. Wide, shallow ditches may be required. In this case, the cross-section method of loading—with one to two cartridges in holes 18 in. apart made in cross rows 3 to 4 ft apart—should be used. Large ditches, up to 30 ft wide and 12 ft deep, can be made with the post-hole method—loading a row of holes, up to 6 ft apart, with up to 50 lb to the hole. Larger ditches have been made with this method. On all jobs of this type an experienced blaster should be employed.

Practical experience has proved that a dam built temporarily and close to the proposed head of the new channel is a decided advantage in turning the water into the new channel.

A great many people do not appreciate the *scouring action* of *flowing water*. In certain types of soils, a 3½-ft drop per mile is sufficient to scour a ditch continuously and to increase its depth. In other types of soil, twice that drop per mile does not affect the cross-sectional area of an operating ditch.

A great many times—particularly in connection with the straightening of streams or the changing of a channel of a river—the scouring action of water can be employed to advantage. Particularly is this true during periodic high water stages.

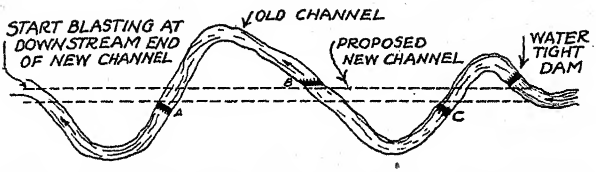


Fig. 203—In straightening streams by blasting it is frequently necessary to build dams to force the water through a new channel as shown at points (A), (B), and (C).

Approximately a cubic yard of material is thrown out when a pound of ditching dynamite explodes. In addition, a certain yardage of material surrounding the blasted area is loosened and will wash readily wherever there is a sufficient volume and flow of current.

In Figure 204-A a cross-section is shown of the blasted ditch and the loosened area which may be scoured by the action of the stream. A shallow load is placed at a point one-half the actual depth of the required ditch.

If it is planned to use the maximum scouring action of water, a different loading method will be necessary. Figure 204-B is a cross-section of what happens when the load is placed too deep for throwing the maximum amount of earth clear of the ditch. This cross-section also shows the expanding forces at the instant of the explosion. Dynamite explodes equally in all directions, and forms a hollow cylinder surrounding the loads until they break through the surface releasing the gases and expelling some of the material. The position of the load is usually three-fourths of the required depth of ditch.

The effect of the explosion is to create a cavity into which falls some of the sides AA (Figure 204-B). The earth which has fallen into the cavities, or trench, caused by the explosion and the loosened material in the bottom of the new ditch will be scoured out to the required depth by the volume and speed of the water flowing through the new ditch. The ultimate result will be a ditch of at least the required depth and with nearly straight sides.

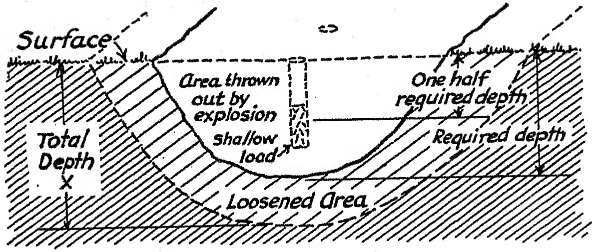


Fig. 204-A—Cross section showing loosened area caused by ditch blast

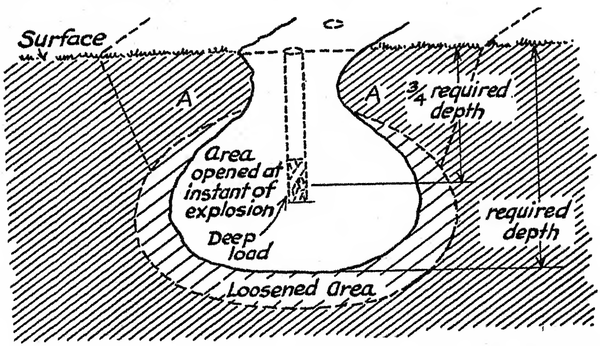


Fig. 204-B—The immediate effect of loading explosive charges deeply. Sections AA fall soon after the blasting and a greater area is loosened and will be scoured out by the water than results from the same charge located as in Figure 204-A

As evidence of the effect of blasting upon the soil which must be removed to make a new channel, an "ox-bow" was taken out of a river in Maine by the deep loading method. In the fall the blast was made; the area thrown out was approximately 0.6 of a cubic yard per pound of dynamite, but a large soil area was loosened. In the following spring, high water washed a large amount of the loosened material out of the channel blasted the previous year. Actual measurements taken in the spring proved that more than four cubic yards of material had been removed per pound of dynamite, aided by the action of the water. The entire river now goes through the cut-off leaving the "ox-bow" practically dry.

Another example of the scouring action of flowing water has been demonstrated in cut-off work on the Mississippi River. The usual procedure is to make a channel with a 250 ft bottom with a hydraulic dredge. In due time the action of the water will widen this to 4,000 ft. Dynamite has been used to assist this process, particularly when matted cypress stumps and heavy blue gumbo clay are encountered. The fracturing action of explosives on this clay has caused from 10 to 20 yds of material per pound of dynamite to be washed away in a short time.

Wherever the conditions permit the use of the methods just described, careful consideration should be given to their adoption. In some cases these methods are not applicable, for example, where the mud is too soft to blast or dig or where its depth is considerably greater than the depth of the required ditch. Successful ditch blasts have been made in this very soft material, however, where there was a drop of 6 ft or more to the mile across the area and the entire length of new ditch was shot as one blast. Under these circumstances the flow of water started and scoured before the mud had a chance to enter and fill up the new ditch. Under other circumstances it was necessary to use sheet piling or other similar construction and to dig out the ditch.

TABLE XVI

Charges of 50% Straight Dynamite for Blasting Ditches by the Propagation Method

Top width of ditch	Approximate number of 1¼"x 8" cartridges per hole required for various depths				Number of parallel rows required	Distance between rows in inches
	2½ to 3 ft	4 ft	5 ft	6 ft		
6	1	2	..	..	1	..
8	1	2	3	..	1 or 2	30
10	1	2	3	5	2	36
12	1	2	3	5	2	42
14	1	2	3	5	2	48
16	1	2	3	5	3	36
18	1	2	3	5	3	42

The charges above are approximate for holes spaced 24 inches apart—the exact spacing determined by three or four test shots.

TABLE XVII

Charges for Electric Ditch Blasting

Approximate top width of ditch in feet	Approximate number of 1¼″x 8″ cartridges required for various depths			Number of rows of holes required	Distance between rows in inches
	2½ to 3 ft	4 ft	5 to 6 ft		
3	1	..	..	1	..
6	2	4	..	1	..
8	2	4	6	1 or 2	20
10	2	4	6	2	28
12	2	4	6	2	36
14	2	4	6	2	42
16	2	4	6	3	42
Required Length of No. 6 du Pont Electric Blasting Caps					
	4 ft	6 ft	6 to 8 ft		

TABLE XVIII

Dynamite Required for a Given Length of Ditch

Spacing	10 Rods		Quarter Mile		Half Mile	
	Number of holes	Dynamite required using charges of one cartridge per hole	Number of holes	Dynamite required using charges of one cartridge per hole	Number of holes	Dynamite required using charges of one cartridge per hole
18 in.	110	55 lb	880	440 lb	1760	880 lb
20 in.	99	49 lb	792	396 lb	1584	792 lb
24 in.	83	41 lb	664	332 lb	1328	664 lb
26 in.	76	38 lb	608	304 lb	1216	608 lb
28 in.	71	36 lb	566	284 lb	1132	566 lb

1 rod = 16½ ft. 10 rods = 165 ft or 55 yd.
Quarter mile = 1320 ft or 440 yd or 80 rods.
Half mile = 2640 ft or 880 yd or 160 rods.

SOIL BLASTING AND TREE PLANTING

Vertical Drainage. This type of drainage can be used only when the trouble is caused by hardpan holding the excess moisture on or near the surface of the ground; and where there is an underlying bed of sand, gravel or other loose material through which the water can drain away as is shown in Figure 205. It is accomplished by drilling a hole almost through the hardpan and loading it with a sufficient amount of "Red Cross Extra" Dynamite 20% or 40% distributed along the borehole, to shatter the entire layer of hardpan. When the hardpan is of a gritty nature, no further treatment is needed; but when it is slimy or silty the loading must be heavy enough to create a rough well or crater, which is filled with any sort of available rubbish, such as brush or boulder and stump fragments. This acts as an open drain. The details of the work are shown in Figure 206.

Vertical drainage is practicable for draining clay pits, roads, railroads, fields, ponds, and many other places. In a slightly different application it can be used for the disposal of sewage, spent dyes and laundry waste water. If possible, the blasting should be done when the soil is dry, though good results have been obtained when the water was so deep as to require the use of a boat or float for loading. When the boreholes cannot be kept open long enough to load the explosives, use should be made of old pipe or boiler tubes. These can be slipped into the boreholes, cleaned out with a pump or auger, and the charge loaded inside.

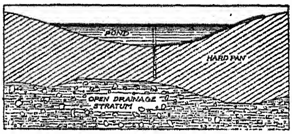


Fig. 205—When ponds are caused by tight material over open material they can be drained by deep blasting

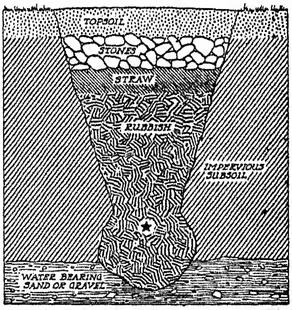


Fig. 206—Diagram of deep draining hole showing the use of rubbish to prevent the hole from becoming clogged with fine clay

It is best then to hold the charge down with a tamping stick and draw the pipe. When this is not possible, the charge must be heavy enough to do double work in splitting the pipe and shattering the hardpan at the same time.

Subsoil Blasting. When the fertile topsoil is underlaid by a thin stratum, say not more than 8 to 10 in., of hardpan, shale, or cemented gravel, so that rainfall cannot seep down and be stored up in the subsoil and roots cannot penetrate deep enough to afford the plants strong growth, it is often beneficial to shatter this impervious material by blasting.

The procedure is to punch holes down to the center of the impervious stratum, spacing them about 15 to 18 ft apart, load each with a half cartridge of "Agritol" or "Red Cross Extra" 20%, primed either with a blasting cap and safety fuse or an electric blasting cap, but usually the former, and tamp the holes full of earth. When the charges are fired, the surface of the ground should show a slight bulging over each charge but no earth should be thrown into the air. A small pot hole will probably be formed at the bottom of each hole, and these should be filled by caving in topsoil.

Subsoil blasting should be done only when the soil is dry.

Tree Rejuvenation. By tree rejuvenation is meant blasting around the roots of grown fruit, shade and other trees to invigorate their growth. If carefully done it may prove beneficial especially on tight clay and hardpan soils where the trees are not growing properly.

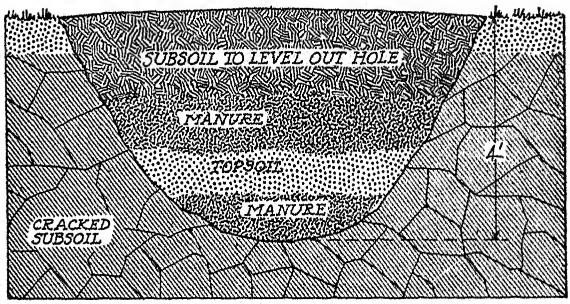


Fig. 207—In poor soils, holes for rejuvenating failing trees should be blasted quite heavily and the craters filled with layers of manure and soil or with a rich mixture of soil and fertilizer

Ordinarily the blasting should be done in exactly the same manner as for subsoiling. If the soil is deficient in plant food or organic matter the holes should be loaded more heavily so that the blast will blow out an open hole which can be filled with layers of soil and manure or with soil mixed with

fertilizers (Figure 207). For young trees the blasts should be placed not closer than 6 to 8 ft from the trunk of the tree (Figure 208). For old trees they should be about under the extreme spread of the branches (Figure 208). Such treatment has been known to have a considerable effect in destroying nematodes and similar diseases of the roots.

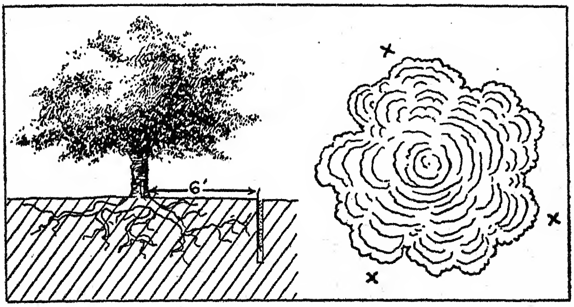


Fig. 208—Location of charges for rejuvenating trees

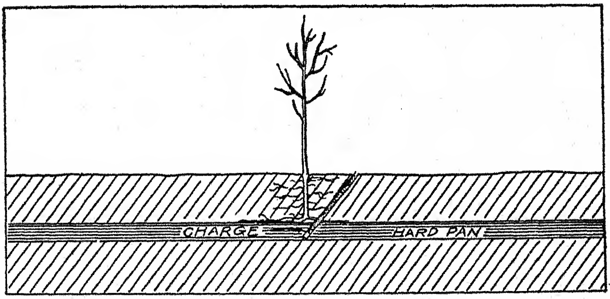


Fig. 209—Correct location for a blast in the hard pan under a tap-rooted tree; the charge must be light

When trees are stunted by the tap root coming in contact with hard pan, relief may occasionally be obtained by shattering the hard pan immediately under the tap root with a blast placed as shown in Figure 209. The charge must be very light, usually about one-quarter of a cartridge of "Agritol" or of "Red Cross Extra" 20%. A heavy blast would so damage the roots as to injure the tree. This treatment should be accom-

panied by very small blasts placed around and among the lateral roots.

Tree Planting. Blasting for planting trees is advised in all soils except open, well-drained sandy and gravel soils. The work must be done when the soils, especially clay soils, are dry. When such subsoils are blasted wet, there is trouble from the soil around the blast being compacted. The blasting can be done at planting time, but a better practice is to blast some time in advance. Manure, commercial fertilizers, or ground limestone can be added to the holes if needed.

The work is simple. A borehole is punched into the ground and loaded with a half-cartridge charge of "Agritol" or "Red Cross Extra" 20%, or if the soil is hard to break or the holes are deeper than 36 in., with a slightly heavier charge. A blasting cap and fuse are used for priming and the hole is well tamped.

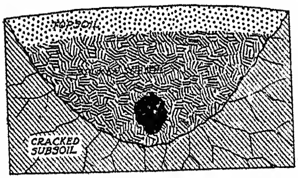


Fig. 210—The blast thoroughly cracks the soil but usually leaves a cavity or pot hole at the bottom which must be filled

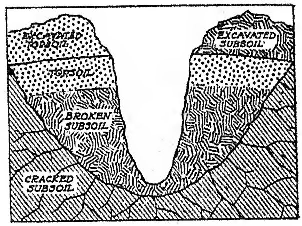


Fig. 211—The best practice is to shovel out the loose soil and expose the pot hole

The shot will loosen the soil for a considerable distance and form a pot hole or cavity at the base (Figure 210). The loosened soil is shoveled out to expose the pot hole (Figure 211), which is then filled with topsoil up to the level where the tree is to be set (Figure 212). This filling must be tamped or tramped to prevent any settling after the first heavy rains.

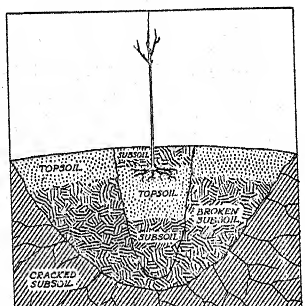


Fig. 212—As much of the hole as possible should be filled with rich topsoil, thoroughly packed, and then the roots of the tree should be set as they were in the nursery

The tree is set in a natural position. Both top and roots should be pruned.

This method of planting is advisable for all kinds of fruit, shade, and ornamental trees.

When the subsoil is extremely hard, it should be blasted at frequent intervals between the trees as described for subsoiling.

TABLE XIX

Quantity of "Red Cross Extra" 20%
Required per Acre for Subsoiling or Planting Trees

Distance Between Trees Square Method	Trees per Acre	Amount of Dynamite per Acre Using ½ Cart. per Tree	No. 6 Blasting Caps per Acre
15 ft	196	49 lb	196
20 ft	110	28 lb	110
30 ft	49	13 lb	49
40 ft	25	7 lb	25

CHAPTER XX

SHOOTING IN SEISMIC PROSPECTING

One of the specialized uses of explosives is in connection with the seismic method of prospecting for oil. Basically, seismic prospecting consists in artificially creating earth vibrations and recording and interpreting these vibrations. Explosives detonated by electric blasting caps have proved to be the best means for initiating these earth tremors.

Instruments known as geophones are used to detect these artificially created earth vibrations. These geophones are so constructed that the earth tremors are converted from mechanical energy into electrical energy after which the latter is transmitted by means of connecting wires to the recording truck. At the recording truck, the faint electrical impulses are amplified much in the same manner as radio waves are amplified in the usual commercial receiver. These amplified impulses are then utilized to actuate a suspended mirror. A light beam is focused on this mirror and any movement of the mirror causes deflections of the light in proportion to the frequency and amplitude of the electrical impulses. The reflected light is photographed on a moving film and a permanent record is thereby obtained which shows the character and magnitude of the original earth vibrations. These records, which are interpreted by the seismologist, yield a very accurate picture of the type and location of underlying strata in the area.

The personnel carrying out seismic prospecting in the field are known as seismograph crews. These crews are maintained by an oil company or by an organization specializing in seismic research, which leases the services of its crews to the oil companies. The usual seismograph crew comprises (1) the party chief, (2) the seismologist who interprets the records, (3) the survey group which maps the area being prospected and locates the proper points for subsequent tests, (4) the drill section which drills the holes for receiving the charges of explosives, (5) the shooter and his assistant who have charge of the explosives and the loading and firing of charges in drill holes, and (6) the observer and his assistants who take care of the receiving and recording of the earth vibrations.

Seismic prospecting may be divided into two general types: the refraction method and the reflection method.

REFRACTION METHOD

With the refraction method, the study normally deals with the transmission speed of earth vibrations *through* underlying earth formations and is utilized to a major extent in the detection and mapping of large structures, for example, salt domes. Under these conditions, the geophones and recording trucks are normally located on the arc of a circle at a considerable distance from the point where the explosives are detonated, distances as great as 6 to 10 miles not being unusual.

In the early days of seismic prospecting in this country when the refraction method was in general use, the explosives used to initiate the earth vibrations were merely placed on the surface of the ground and in some instances were not even removed from original containers. The only characteristics required of the dynamite were proper strength and velocity.

In view of the distances between the shot point and the recording instruments, and the fact that the explosives charge was shot unconfined, the amount of explosives necessary to obtain the desired vibrations was normally quite large. In some instances explosives charges ranging as high as 2,000 lb per shot were necessary.

The electric blasting caps used in refraction prospecting had the main purpose of efficient initiation of the explosives charge and no particular consideration was given to the speed of detonation of these caps. A record of the time of detonation of the explosives charge was, of course, essential in order to allow intelligent interpretation of the completed seismic records, but this instant of detonation was secured by placing a "shot moment" wire in contact with the dynamite charge. This wire was connected into the timing circuit at the recording truck, and the breakage of this wire by the explosion provided the desired record.

Later modification of the refraction method included the use of shallow holes with water tamping or well drilled water-filled holes into which the explosive was loaded by means of metal torpedoes. Less explosive was consumed in these modified procedures, but the only additional explosives requirement was that of a moderately good water resistance. The most popular grade proved to be 60% Special Gelatin. The requirements as outlined just above for electric blasting caps remained

practically unchanged, except that in this product also some water resistance was necessary.

REFLECTION METHOD

The reflection method was developed because numerous areas were encountered which did not lend themselves to exploration by means of the refraction method. During recent years, it has almost entirely replaced the refraction method.

With the reflection method the study entails, as the name implies, the reflection of earth waves *from* underlying strata and is used primarily to secure a subterranean map showing the thickness, depth, and angle of inclination of underlying beds of material. With this procedure the geophones and recording trucks are usually located quite close to the point where the explosives charge is fired. The geophones are normally placed in a straight line from the shot point and the first geophone may be only a few hundred feet from the explosives charge.

With the reflection system the shot holes are generally 3 to 5 in. in diameter and from 25 to 500 ft deep. The charges of explosive normally vary from 1 to 20 lb, and the holes are filled with water to provide the necessary confinement and also to lower the temperature of the holes. In most cases firing takes place soon after loading, although in some instances several days or even longer periods are allowed to elapse. A number of shots may frequently be made in the same hole to obtain check records or to secure data in different directions from the shot point. Since holes are not cleaned out between shots, difficulty may be met in loading successive charges due to caving or bridging induced by a previous shot.

It is evident from the foregoing that reflection prospecting places very specific requirements on blasting agents. It is necessary that they be (1) sufficiently water resistant to withstand high heads of water, (2) properly designed so that such water heads will not cause desensitization through the pressure effect alone, (3) packaged so that the resulting cartridge is stiff enough to allow forcing through muck and sand in the drill hole, and (4) of a composition which will permit fairly rough handling in the drill hole without undue hazard.

Three types of du Pont blasting agents are available which are designed especially for seismic prospecting, two of these being gelatins and the other "Nitramon" S.

Gelatin Grades. The gelatin grades are Seismograph "Hi-Velocity" Gelatin 60% and "Seismogel" which also possesses

60% strength. These two grades are cartridged in special rigid shells, the latter being of the convolute type, that is, made by utilizing paper of the proper length for the shell and rolling it into a tube with glue between successive layers of the paper. "Seismogel" and Seismograph "Hi-Velocity" Gelatin 60% in convolute tubes are offered in standard sizes of 2 in. by 2½ lb and 2¼ in. by 5 lb.

"Seismogel," which is a modification of Special Gelatin 60%, is intended for use in holes where the water depth does not exceed 100 ft. Seismograph "Hi-Velocity" Gelatin 60% is offered for use in particularly deep holes where exceptional water resistance and ability to detonate completely and at maximum velocity under high water pressures are required.

Detailed information on gelatins in general, and seismograph gelatins in particular, will be found in Chapter II.

The satisfactory loading of seismograph gelatins in drill holes is very much more complicated than is the case with the usual types of blasting. As explained above, the holes are relatively deep, and since a number of shots may often be made in the same hole, the holes are ragged and frequently obstructed. This condition brings about the necessity for the rigid cartridges just described and also makes essential the use of the proper means of forcing the gelatin into obstructed holes.

Each seismograph crew has a set of loading poles which comprise wooden poles approximately 1 to 1¼ in. in diameter and 10 to 15 ft in length. These poles are equipped at either end with a suitable joint, so constructed that one pole may be joined to another when the two are at about right angles, but so that the two poles cannot be separated when in a continuous line as is the case in a drill hole. The pole which is introduced into the hole first is equipped with a means for holding the gelatin charge during loading, the two most popular types being a long brass pin or spear which is pushed down into the first cartridge of the gelatin charge, and the second being a "side spoon." The latter is a curved brass piece which runs along the length of the gelatin cartridge and which conforms to the contour of the gelatin stick. The charge is tied to this spoon during loading and the spoon is pulled free when the charge is in the desired position.

In some locations it is practically impossible to keep a hole open after drilling and under such conditions a metal casing is used from the surface of the ground to a point near the bottom of the hole.

In view of the nature of the holes frequently encountered in seismic prospecting, and the difficulty in loading such holes, emphasis should be placed on safety. It is true that gelatin will withstand a surprising amount of abuse without detonating but it must be considered also that an electric blasting cap is imbedded in the gelatin and under very rough handling this detonator may be dislodged and be detonated during the loading operation. In forcing a gelatin charge into the hole, as even a pressure as possible should be used and churning of the explosive and sharp blows against it should be avoided.

"Nitramon" S. Chapter III gives a complete description of Du Pont "Nitramon" and its advantages as a blasting agent. "Nitramon" S, the special product of this type for seismic prospecting, is also described. As stated therein, "Nitramon" S is contained in metal cans which are carefully designed for ruggedness and resistance to water pressure, and they are threaded at the ends so that they may be joined securely with positive contact between cans. With this feature, charges can be conveniently assembled, with as many units as desired, to form a continuous column characterized by exceptional rigidity throughout its length. "Nitramon" S is detonated by a special primer which is also contained in a metal can. One end of this primer can is threaded so that it can be attached to a charge of "Nitramon" S and the other end is provided with a tube to hold an electric blasting cap and with a threaded recess to accommodate a special shield which protects the cap and holds it in place.

"Nitramon" S has met with wide acceptance by the seismic trade because of its safety features and because of the rigidity of the individual cans and of a column of cans. As a matter of fact, it has been found in many cases that because of the rigidity of a "Nitramon" S column, the casing, essential in certain locations with other seismograph blasting agents, may be eliminated.

The loading of "Nitramon" S in drill holes is similar to the method used in the case of seismograph gelatins except that some modifications are necessary in the type of loading heads used. With "Nitramon" S, for example, a spear or pin is, of course, not feasible since such a device would puncture the metal container. The two most satisfactory loading devices for "Nitramon" S are the "side spoon" discussed under "Gelatin Dynamites," and a metal cage. Figure 213 shows the loading of a "Nitramon" S charge by means of the "side spoon" type of loading equipment.

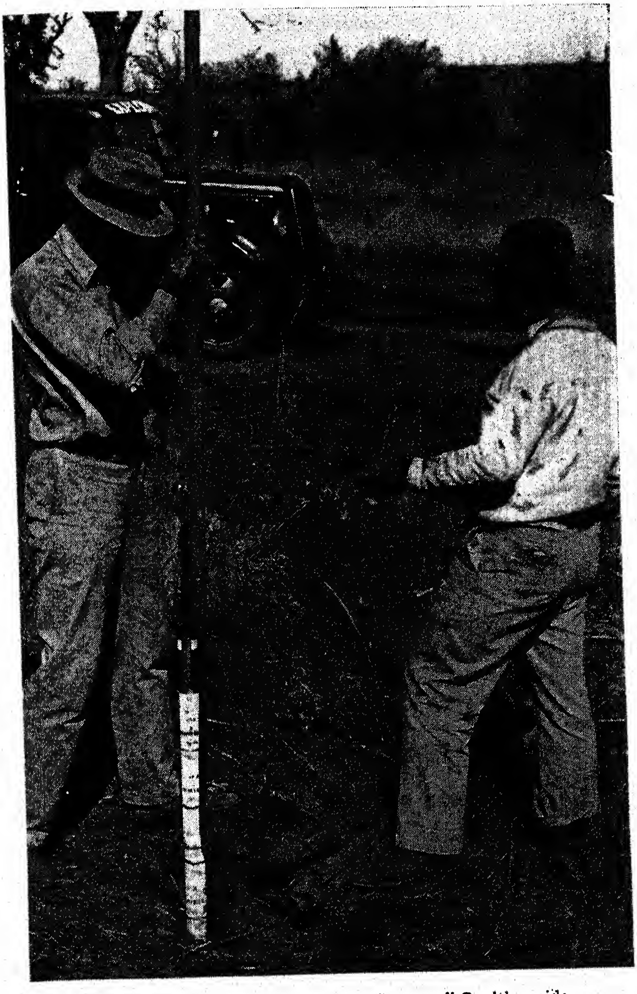


Fig. 213—Loading a charge of "Nitramon" S with a side spoon attached to pole

The metal cage just mentioned is illustrated at the right in Figure 214 and is formed by using metal rods welded together in the manner shown. This cage fits around the "Nitramon" S primer while the charge is being pushed into the hole. When the charge has reached the desired depth an upward pull on the loading poles releases this cage from the primer.

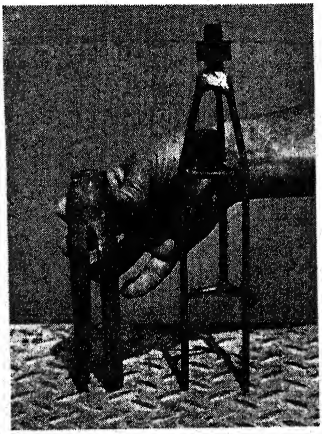


Fig. 214—(right) a cage type loading head with (left) a socket for the pole

Although the blasting composition in "Nitramon" S and "Nitramon" S primers is relatively insensitive to shock and friction, precautions should be taken to prevent undue roughness in loading drill holes with this product. This statement is made primarily because of the presence of an electric blasting cap which, even though protected by the special shield, may be set off if too much force is used.

Electric Blasting Caps. The reflection method of seismic prospecting makes it essential that the electric blasting caps used possess extremely accurate detonation time characteristics. For this reason the "SSS" type of detonator is offered for seismograph use. Detailed information on this cap will be found in Chapter IV.

Because of the depth of holes used in seismograph work "SSS" Electric Blasting Caps are frequently purchased by the consumer with the long length leg wires, that is, 30 to 60 ft and sometimes even up to 100 ft. The type of fold used with these long leg wires is designed particularly to avoid tangling as the charge is lowered or poled into the drill hole. "SSS" Electric Blasting Caps are provided with the rolled metal foil shielded shunt which has been demonstrated to be an outstanding means of protecting electric blasting caps from accidental detonation by stray currents or other electrical sources.

CHAPTER XXI

MISCELLANEOUS USES OF EXPLOSIVES

Explosives are simply a source of concentrated energy that ingenuity can put to work in numerous ways. It is impractical in a condensed handbook to mention all of the possible uses of commercial explosives or to go into any great detail in discussing even the more important applications. In this chapter, however, the more common miscellaneous uses are briefly treated.

EXCAVATING FOR CELLARS, FOUNDATIONS, UNDERGROUND SILOS, WELLS AND SIMILAR PITS IN HARD GROUND

For loosening the ground or stone for most classes of excavations the use of dynamite proves a decided economy, as it does the work quickly, easily, and more effectively than can be done by means of picks.

When the excavation is on a hill or in a location where the cutting begins at nothing or at a few inches, the blasts are placed and loaded as is advised for road cuts.

For starting excavations on level ground or deepening excavations, the blasting is done similarly to shaft sinking.

For soft material the "cut" or first shot may be a single hole. Harder rock will require from 2 to 4 cut holes, fired electrically. The excavation is enlarged by other holes drilled around the crater opened by the cut shot. For heavy clay, hardpan and shale, "Red Cross Extra" 20% or 40% is recommended. For rock, the recommendations made for shafts and tunnels are applicable.

When such an excavation is a cellar and the floor is to be the foundation for a building, care should be exercised to avoid shaking the bottom in such a manner as to injure the ground that must support the foundation of any wall or building.

In blasting foundations in rock where it is desirable to excavate to the furthest possible extent but not to crack the rock beyond a certain line, as in cities where an expensive foundation may be injured by careless blasting in the adjoining property, the method used is to drill a number of vertical holes

at close distances, four to six inches apart, along the line parallel to the party line and as close as practicable. Blast holes are then drilled two or three feet farther from the party line, spaced closer to each other than for open country blasting, and fired with light charges. Usually the break or crack will extend up to the line of empty holes and will follow that, not running into the rock beyond the party line.

Wells are often sunk through rock or ground which cannot be dug to advantage without the aid of explosives. When rock is reached and the earth above is properly supported, a circle of four or five drill holes should be started about half-way between the center and the sides of the well and pointed at such an angle that they will nearly meet each other near the center when they are three or four feet deep. These holes should be loaded about half full of "Red Cross Extra" Dynamite 40%, with damp clay or sand tamping packed firmly above to the top of the hole, and then exploded all together from the surface by electricity. This shot will blow out a funnel-shaped opening in the center, and the well can then be made full size with another circle of holes drilled straight down as close to the sides as possible. If the well is large, it may be necessary to drill a circle of holes between the inner and outer circle. The above process should be repeated until the well has passed through the rock or has been sunk to the necessary depth. Do not in any case enter a well until all the fumes of the last blast have come out. If in doubt, lower a lighted candle to the bottom; if it continues to burn clearly and brightly the well may usually be entered safely. Electric blasting caps will give the best results, as they are less dangerous than blasting caps and fuse and result in better execution by exploding the holes together.

BLASTING OLD FOUNDATIONS

Old concrete walls, foundations or engine beds can be most economically removed by means of explosives.

If it is found necessary to remove a wall of concrete or brick, it can be best done by boring holes either with a hand or power drill at the bottom of the wall. Holes should be drilled to a depth equal to three-quarters of the thickness of the wall and about 4 ft apart for walls 10 ft high or under. From one-half to one cartridge of "Red Cross Extra" 40% should be loaded in each hole and all connected up electrically and fired at one time. If any fear is felt in regard to throwing debris out of bounds, heavy ties or other lumber should be piled against the wall in front of the holes.

For removing concrete foundations or engine beds inside a building, especially if there is other machinery nearby, great care is necessary in the use of explosives. It is best to shoot one hole at a time. If an engine bed, a vertical hole should be drilled a depth nearly equal to the thickness and "Red Cross Extra" 40% used. Holes should be well stemmed with clay. As a general rule about one-quarter of a pound of "Red Cross

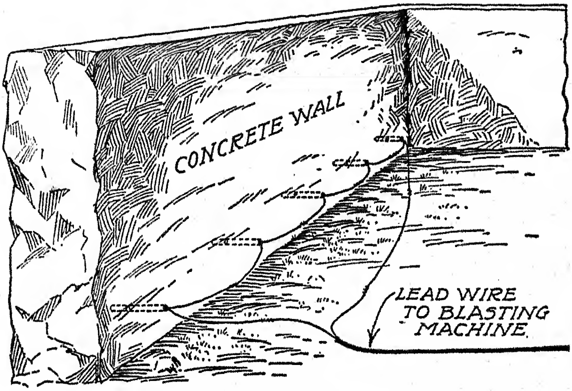


Fig. 215—Light charges fired electrically in the bottom of walls and foundations will shatter them so that they can be easily removed

Extra" 40% should be used per cubic yard of concrete. As an extra precaution it is well to protect adjacent machinery by stacking railroad ties or other heavy timber between it and the blast, or the concrete to be blasted can be covered with a blasting mat before the shot is fired.

If the foundation is very thick, it should be removed by benching—two or more steps, or lifts, being required.

Reinforced concrete is much harder to shoot and an oxy-acetylene torch is sometimes used to cut the reinforcing rods.

Sometimes best results are obtained, especially if the mass is of small section and high, by drilling a horizontal hole near the base. In this case the hole should be drilled to a depth equal to three-quarters the thickness of the block, as in blasting a wall, and loaded in the proportion of one-quarter of a pound to the cubic yard. In all cases be sure to tamp holes solidly and take every precaution to protect nearby machinery.

Experience has taught that the better the concrete the more easily it is broken. It is not necessary in work of this kind to shatter or throw the material too much, but to crush and break it so that it can be easily barred or picked down.

If work is done in the open, several holes can be loaded and fired at one time electrically, with greater efficiency.

When blasting inside a building, all doors and windows should be opened so as to avoid breakage from the concussion.

BLASTING OUT COFFER-DAMS

During the construction of hydroelectric power plants it is often necessary, temporarily to hold back or divert the flow of water. This is usually accomplished by building coffer-dams at the desired locations.

Coffer-dams are generally constructed by bolting together a cribwork consisting of heavy logs or squared timber, and filling the structure with broken rock to give it weight and strength. The front is usually sheathed with boards to prevent water seepage.

After the coffer-dam has served its purpose, having enabled work to be carried on in the dry, it is often necessary to remove it. This can sometimes be done by hand but this is a slow and laborious procedure. Removal can more quickly and economically be accomplished by blasting if there are no damageable structures nearby.

If blasting is resorted to, a total charge of from 2 to 4 lb of explosives per cu yd of coffer-dam should generally be used. The amount will ordinarily depend upon the effectiveness with which the removal is to be accomplished. With 2 lb per cu yd the dam should be destroyed without undue scattering, while 4 lb per cu yd should provide thorough scattering of the contents.

From two-thirds to three-quarters of the total charge should be placed along the bottom of the dam, preferably at the crossing of the crib timbers at interior points. About one-quarter of the total charge should be located at certain points along the center line of the dam about half way up from the bottom. These latter charges are for the purpose of breaking up and scattering the upper portion of the dam. Main charges should be spaced at intervals of 8 to 10 ft along the length of the structure. There should also be some small charges placed at frequent intervals along the front of the dam to assist in breaking up the sheathing.

As the explosive may be loaded for several days before firing, it is preferable to use a waterproof one, consequently Du Pont Special Gelatin 40% or 50% is recommended. Each charge should be primed with two waterproof electric blasting caps. All wiring must be carefully protected during the loading and tamping operations. If the charges are fired from a power line it is preferable to connect the caps in straight parallel or in parallel series. If the latter method is used the two caps in each charge should be connected in a separate series.

It is recommended that holes for the charges be built into the dam before rock filling is put in place. This can be most readily accomplished by setting 8 in. diameter metal casing pipe at desired points in the structure. If necessary these casings can be filled with sand to give weight. The sand can then be easily blown out before loading the explosives. If casings are not used it is necessary to prepare for the placement of the explosive charges by excavating every third or fourth compartment of the cribwork. The explosive charges should then be placed and the excavated material replaced before firing.

DIGGING TRENCHES WITH VERTICAL WALLS

For blasting vertical wall trenches, such as pipe line and sewer trenches, the methods recommended for open drainage ditches (Chapter XIX) are not applicable, as the soil is blown away, the top is too wide, and back filling is expensive. In this case all that is needed is a complete loosening of the rock or ground.

The soft, easily dug earth is removed from the top so that the hard ground or rock is exposed to the full width of the trench. One or two sloping holes similar to the cut shot in Figure 216 are used to loosen the ground to the desired depth. This creates a pit or opening into which subsequent blasts throw the loosened earth.

Holes are then drilled along the center line of the trench as is indicated in Figure 216. Ordinarily these should be fired in succession in order to overcome the difficulties encountered when long lines are fired. In cities or towns each hole should be fired separately with an electric blasting cap, for added safety.

Often it is necessary to blast a trench at the bottom of a river to permit the laying of pipe lines for gas and oil. A line of holes is drilled across the stream in the center of the proposed

trench. Sometimes well drill holes are used and at times wagon drills putting down two or more rows of holes. Drills are

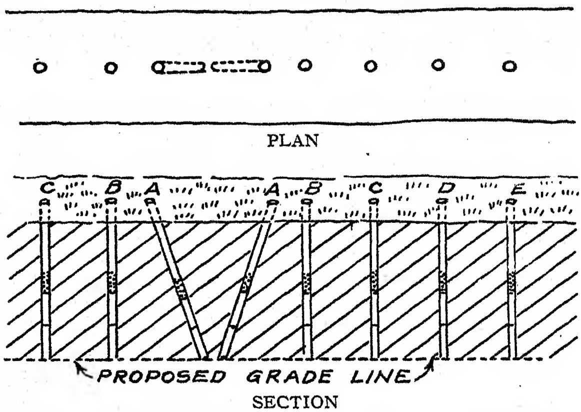


Fig. 216—Method of loading a sewer or pipe line trench; the holes (A) are fired and the debris cleaned out; then the other holes (B), (C), (D), etc., are drilled and fired in succession

mounted on scows. In rock, gelatin dynamite from 50% to 60% strength is used, loading about 1¼ lb per cu yd in place. Usually all holes are primed and fired with "Primacord."

DIGGING POLE HOLES AND SETTING POLES

Digging Post and Pole Holes. Dynamite is useful in digging both shallow and deep holes for fence posts and for telephone and other classes of poles.

First, remove the soft surface to a depth of from 6 to 8 in., or down to the hard ground, and to the full diameter of the desired hole. This will prove helpful even where there is but a few inches of soft ground. The hole is then ready for punching the borehole for loading.

For shallow holes drill or punch a borehole in the center by a suitable method to about the depth of the desired hole and load it with a small charge of "Red Cross Extra" 20% or Du Pont "Extra" primed with a blasting cap and fuse. The holes should be tamped. Such a blast will so loosen the hard ground or shale as to make shoveling easy (Figure 217-a).

For deep holes the borehole should be several inches deeper than the desired pole hole. The charge is prepared by cutting the dynamite cartridges into pieces from $1\frac{1}{2}$ to 4 in. long and tying them to a lath, the top piece being primed. The entire charge is lowered into the hole (Figure 217-b), so that the primer is some 18 to 20 in. below the surface, and fired. The effect of the blast is to spring the soil back and form the hole. As the blast has affected the soil to its full depth the hole is deeper than needed. This allows a space for the trimmings chiseled off the sides to fall, thereby reducing the amount of spooning required to complete the hole. The explosive recommended is Du Pont Straight 40% or stronger.

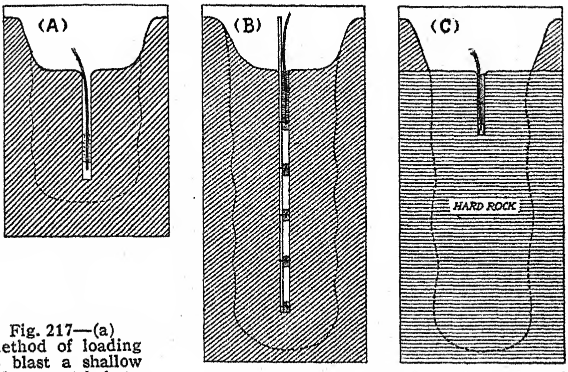


Fig. 217—(a) Method of loading to blast a shallow pole or post hole to loosen the soil so that it can be easily shoveled. (b) Loading a deep hole showing relative positions of the primer and charges tied to a lath. (c) Method of loading to blast a pole hole in solid rock; the borehole must not be deep and after the first blast has been cleaned out, a second hole should be drilled and blasted. (Dotted line indicates the shape of the blasted holes)

As it is impossible to force back the sides of the holes in solid rock, as is done in blasting in hard clays, modifications in the method of loading are required for these holes. After excavating the hole down through the soil, if any is present, drill a hole from 12 to 18 in. into the rock. Load this with a full cartridge primer located in the bottom, tamp the hole tight, and fire (Figure 217-c).

If the loading is heavy enough this will shatter the rock to the full depth of the blast. When the loose fragments have been

removed, drill another hole to about the same depth and load as before. The explosive used for this work should never be of a lower strength than "Red Cross Extra" 40%, and for hard rock 50 or 60% strength is often better.

Setting Poles. In soft, plastic soil and in swamp land flooded with water where caissons are ordinarily required to keep water and soil from filling up a pole hole before the pole can be set, considerable success has been achieved in blasting the hole and setting the pole in one operation (Figure 218). A hollow drill, generally 1½-in. pipe, is driven to the depth desired for the bottom of the pole and the soil is forced out through the lower end of this drill by means of a ram. If the soil is such that it would tend to clog in the pipe and resist ramming, a sand point is used on the end so arranged that the pipe can be withdrawn, leaving the sand point in the hole.

In either case, the charge of dynamite, primed with an electric blasting cap, is pushed down through the pipe to the bottom and the pipe is withdrawn. Then the pole is placed upright on the surface of the ground directly over the charge, being held in place by pike poles or four-way rigging, and the charge is detonated. The explosion creates a pear-shaped pocket and as the gases rush upward the pole settles into this cavity and the natural ground and water pressures automatically press the soil back into the pocket and usually pack it solidly enough around the pole to hold it firmly. Sometimes, after the pole settles,

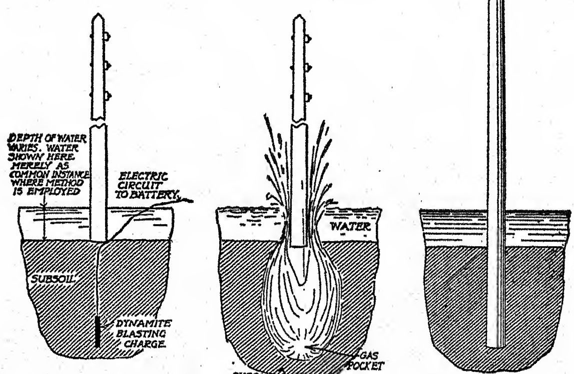


Fig. 218—Setting poles in soft plastic soil by blasting

it is necessary to tamp earth around it in order to fill the pocket completely and hold the pole fast.

If the charge used does not result in sinking the pole to the depth desired, the drill may be driven down alongside the pole, and a second charge loaded and fired.

Poles as long as 100 ft have been set in holes from 14 ft to 16 ft deep by this method. It is not recommended in soil where a hole can be dug or blasted without danger of its caving in before the pole is set.

The following table of charges is derived from experience obtained using this method of setting poles, but, of course, it is only suggestive. Soil conditions at a particular location must always be considered.

TABLE XX

Charges of Dynamite for Setting Poles

Type of Soil	Depth of Hole	Charge 40% Straight
Swamp with muck below	6′ to 7′	2½ cartridges
Swamp with muck and rock underlying	5′ to 7′	3 cartridges
Sand and water	7′ to 7½′	3 cartridges
Coral rock	6 to 7′	4 to 5 cartridges

BLASTING LOG JAMS

Log rafts or jams, on careful examination, are usually found to be held together by a log or several logs acting as a key or pivot. It is against this point that attention should be directed. The use of heavy charges of dynamite is usually necessary. The loading should be done as quickly as possible, as it is usually dangerous to remain long on the jam. The dynamite can be loaded into a bag or box, primed and placed in the water as near the key logs as possible. Firing should be by means of electric blasting caps, as there is danger of the loader having difficulty in reaching a point of safety when using blasting caps and fuse.

BLASTING ICE JAMS

Frequently ice jams so choke running streams as to cause serious danger to bridges, dams and other structures. Blasts to break these up should be directed at the key or pivotal

points of the jam. The most common mistake is to underload. Two general methods of loading are practical.

(1) Holes are cut through the ice at frequent intervals and the charges, the quantity of which must be governed by the thickness of the ice, tied to blocks of wood, thrust through the holes and allowed to float under the ice a little way from the holes. Such blasts heave the ice and thus break it apart. (Figure 219).

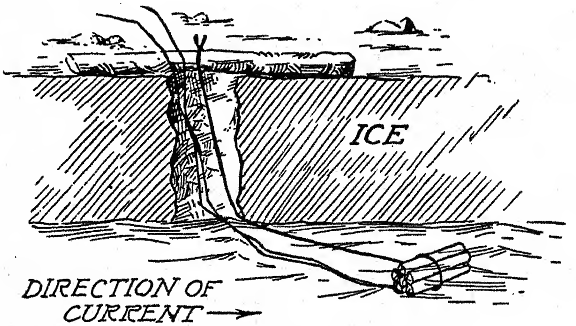


Fig. 219—A bundle of cartridges primed with an electric blasting cap floating under an ice floe; when fired, the explosion breaks up the ice and allows it to float away

(2) Large mudcaps are loaded on the top of the ice at frequent intervals, and fired.

As this work must, as a rule, be done on short notice, little time is afforded to obtain the correct explosive, so the recommendation is made for any low freezing dynamite available. Electric firing should be used for safety as well as for the benefits derived from all charges firing at exactly the same time.

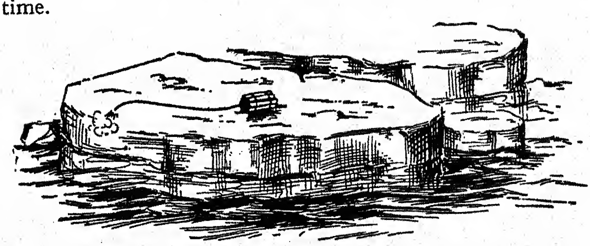


Fig. 220—Showing a bundle of cartridges tied together and primed with cap and fuse used to mudcap floating pieces of ice

Moving floes of ice must usually be broken by the second method. The explosive primed with a blasting cap and a short section of fuse can be dropped on the floe from the shore or from the down stream side of a bridge. (Figure 220.)

It is difficult to give any definite amounts of explosives to be used for blasting ice, but where the broken ice is 3 or 4 ft thick, the charge of explosives should be not less than 10 lb. Where the ice jam runs up to 20 and 30 ft in depth, it may require 1,000 or 1,500 lb of dynamite fired under it to obtain any results.

BREAKING AND CUTTING STEEL

Scrapping Heavy Machinery. The method of blasting heavy machinery for breaking it into scrap must depend on the nature of the material. Large castings are usually broken by mudcaps used in the same manner as for boulders. (See Figure 196), Chapter XIX. The explosive recommended is Du Pont Straight Dynamite 50% or 60%. Occasionally a bolt hole makes an excellent place for loading a block hole shot.

Old retorts, stills and other hollow castings can be easily broken by filling with water and suspending charges of one cartridge of any available dynamite so that they hang in the water and about 6 or 8 in. from the side of the vessel. Electric firing is always preferable and must be practiced when more than one charge is used in a vessel. In this blasting the concussion is carried through the water to the sides of the vessel. (Figure 221.)

Old boilers may be scrapped as has been described for retorts, or sheared apart by using long mudcaps along the plate seams.

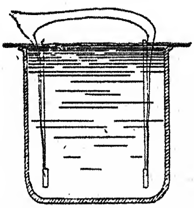


Fig. 221—An open vessel is filled with water and a charge of dynamite properly primed is lowered to a point near the thickest or strongest metal, but not in contact with the metal, and fired there. For large vessels two or more charges are used and fired electrically

When there are buildings near at hand that may be damaged by flying bits of iron, use should be made of either blasting mats or a substitute of tree boughs or planks.

Shearing Steel. Structural steel shapes and forms consisting of riveted plates can be very easily broken up and sheared off by using 50% Du Pont Straight Dynamite in a long mudcap strung along the riveted seam or joint. (Figure 222.) In calculating the charge for this type of blasting the following formula is sometimes used:

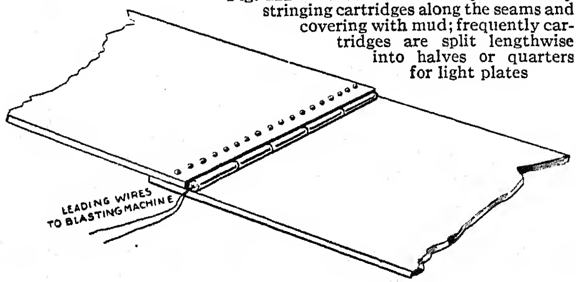


Fig. 222—Plates can be readily sheared by stringing cartridges along the seams and covering with mud; frequently cartridges are split lengthwise into halves or quarters for light plates

$$C = 2\tfrac{1}{2}\, Wt^2$$

where C = the charge of 50% Straight Dynamite in pounds
W = the width of the section in feet
t = the thickness of the plate in inches

It is also advantageous under certain conditions actually to shear the steel of rolled shapes or built up members. Quite frequently it is desired to blast down a bridge truss by cutting all points of support simultaneously. This can be accomplished by placing the proper charges of 100% Blasting Gelatin in intimate contact with the steel member along the shearing line and firing all charges together electrically. A small cartridge is easier to handle, usually 1¼"x 8" with the wrapper removed. (Fig. 223.) A practical loading factor is one pound of Blasting Gelatin for each 5 sq in. of section to be sheared. It is often feasible to cut partly

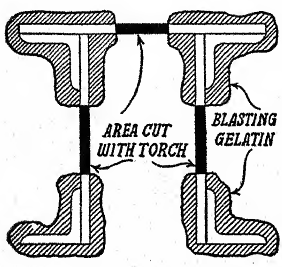


Fig. 223—Cross section of a truss member showing Blasting Gelatin in place

through the section with a blow torch leaving sufficient metal only to support the weight of the bridge, the remaining steel then being cut with explosives.

Blasting Salamanders. At all steel mills it is often necessary to break up salamanders. The easiest and cheapest way to accomplish this is by the use of high explosives.

Mudcapping salamanders is not very successful because of the presence of slag, silica, etc.; and it is tough and hard to break. The better way is to drill holes into the piece, and load with a high strength, quick-acting explosive.

The holes should be drilled to a depth at least equal to three-fourths the thickness of the piece. Best method of drilling is by burning with an oxygen torch. Sixty per cent straight nitroglycerin dynamite or gelatin of higher strength is recommended. Before loading the explosives the holes should be allowed to cool off, which can often be accelerated by introducing water or compressed air.

With electric firing care should be used to prevent a premature explosion from stray currents and also to prevent current leakage. Shunted enameled wire caps should be used and bare connections should be protected with friction tape.

CHAPTER XXII

PRECAUTIONS AFTER BLASTING

RETURNING TO THE FACE

Good practice requires that no one return to the face after a blast until sufficient time has elapsed to allow the smoke, dust and fumes from the explosion to clear away. This precaution applies particularly to underground work. It also applies, however, to outside work, since under certain atmospheric conditions the smoke may hang over and obscure the scene of a blast for a considerable period of time. Rushing into this smoke in an attempt to see the results of the blast is not only unpleasant, but actually hazardous since the vision is so obscured that dangerous roof conditions, falling rocks, and slides may not be seen in time to avoid them, and frequently men may stumble over pieces of rock on the ground and sustain painful injuries. In addition to this, the fumes from a shot of any type of explosive contain toxic ingredients in quantities which may be harmful. Finally, misfires or burning holes may occur at the face and these should not be approached until there is no likelihood of their exploding. A few minutes' wait until smoke dissipates cannot have any effect on the results and will allow everyone to return in safety.

Before any drilling is started in a face which has been blasted, a thorough examination should be made to discover unexploded dynamite. If found, it should be reblasted immediately, using a fresh primer as discussed later in this chapter

HANGING ROCKS AND SLIDES

In many types of underground blasting and in most quarry work, pieces of rock weighing from a few ounces to many tons may be left hanging loosely in the roof or on the face immediately after the blast. These can fall with very little warning or disturbance and if a workman heedlessly walks near them through the smoke, he stands a chance of being trapped before he is aware of his danger. In underground work, the first person to approach the face after a blast should be equipped with a scaling bar to sound the ribs and the roof and to dislodge loose rock.

In any kind of blast involving large quantities of broken material, the muck pile may not become stabilized for some time and slides involving many tons of rock have been known to descend several minutes after the blast has been fired. Here again, if men are approaching the shot in thick smoke, they may be caught before they are aware of the slide or be so impeded by the low visibility that they are unable to reach a place of safety.

FUMES

As has already been stated, the fumes from a blast, regardless of the explosive used, contain some toxic gases. In blasts using very small quantities of dynamites with good fumes, such as permissible shots in coal mines, there is little need to worry about the disposal of the fumes. The normal ventilation required by law in essentially all states is sufficient to take care of any ordinary situation, but in most other types of work, caution should be exercised in entering the smoke from a blast. Usually, the dynamites used in underground work other than coal mines are chosen for their excellent fume properties, but it must be emphasized that a shot involving several cases of explosives of even the best fume characteristics may produce enough toxic gases or may reduce the oxygen content of the air to a point that the atmosphere is dangerous to breathe.

It is obvious that the waiting period between the blast and the return to the face can be considerably shortened by ventilation. A discussion of ventilation and ventilating systems is outside the scope of this handbook, but the necessity for artificial ventilation in places where natural ventilation is inadequate cannot be overstressed. *There is no possible substitute for adequate ventilation.*

A good ventilating system accomplishes two purposes, first, it removes the smoke and fumes produced by the blast and by internal combustion engines that now are more frequently used for haulage, etc., in tunnels, and second, it assures a supply of fresh air to the men at all times. In many operations ventilation is confined to air movement produced by the exhaust of the drills and by blowing in compressed air after shooting and between shifts. This is frequently not sufficient to create satisfactory working conditions. An easy and economical method of furnishing pure air to the men at the face consists in setting up a blower fan at the source of fresh air and leading it to the face through flexible tubing such as Du Pont "Ventube" which is water-, acid- and fungus-proof. This not only reduces

the time lost while waiting for fumes to clear, but increases the efficiency of the men at work.

In underground operations conditions may be improved by spraying the face and muck pile with water. Such a spray helps to lay the smoke and dust, thus improving visibility. It also dissolves certain toxic gases rapidly and further, if sufficient water is used, it displaces the fumes in the muck so that they are more readily swept out by the ventilation.

MISFIRES

Throughout this book an attempt has been made to stress the precautions that must be taken to prevent misfires. It is believed that if the blaster follows the methods of making up primers, loading, priming, tamping, and firing that have been described, the failure of a charge to explode will be an extremely rare occurrence. However, the fact remains that occasionally, for one reason or another, a misfire is encountered and then the blaster wants to know first, how to handle it safely, and second, how to prevent its recurrence.

There are so many different kinds of blasting that it is not possible to give blanket instructions for handling misfires. The blaster must be governed by conditions and he must never lose sight of the fact that working on or near a missed hole is the most hazardous operation associated with blasting. Investigation and correction of the trouble should be left to a careful, experienced man who should be allowed to carry on his work in a methodical manner and without interference.

Under practically all conditions the safest way to dispose of a misfire is to shoot it. However, the laws of certain states, particularly with respect to coal mines, specify other methods.

If electric blasting caps are used, be sure to disconnect the leading wires from the source of power before returning to the blast. If the leg wires are accessible, test the cap with a circuit tester and if it shows a circuit, connect it up and attempt to fire it in the usual manner. This will work successfully if the trouble was caused originally by a faulty connection. If the shot fails again, if the wires cannot be reached, or if caps and fuse are being used, try to shoot the hole with a fresh primer. When the hole contains only a foot or 15 in. of stemming, it is often possible to explode the missed charge by shooting the primer on top of the stemming.

This procedure may fail or be impractical, in which case some blasters remove the stemming, provided it is not specifically forbidden by the mining laws or by local regulations.

Great care must be exercised in this operation to prevent accidents. The use of a metal spoon or auger for digging out the stemming is not recommended because it is difficult to tell where the explosive starts and the blaster may dig into it and set it off. The digging should be done with a wooden tool and it is advisable to keep the stemming wet. About the least dangerous method of removing stemming is to wash it out by means of a stiff rubber hose and a strong jet of water. However, this method ruins the explosive unless it is water resistant. Another practice is to blow the stemming out by means of compressed air. This should also be done with a stiff rubber hose to avoid the hazard of blowing granular explosive out of the hole or into crevices of the rock where it may be exploded if struck with a metal blowpipe. The hose should be equipped with a valve to give easy regulation of the flow of air or water. The use of an iron pipe or even a pipe tipped with rubber should be avoided. When sufficient stemming has been removed, a new primer should be inserted and the charge fired as already described.

It is the custom in well-regulated quarries to measure carefully the distance from the collar of the well drill holes to the top of the explosive charge, and to use good stemming free from grit. If a charge misfires under these conditions, a hole can be carefully made in the stemming to within a few inches of the top of the charge. Always use a hard wood pole, large enough to make a hole that will readily take a 1¼-in. diameter cartridge. The hole can then be loaded with several cartridges of the strongest and highest velocity dynamite easily obtainable, tamped and shot. This rarely fails to explode the missed charge below. If the stemming is softened by adding a little water from time to time as the auxiliary hole is deepened, the work will be much easier. This operation requires the very greatest care.

If sand or stone screenings are used as stemming, it is difficult to drive a hole through it with a pole and expect the walls of the hole to stand up. Often, however, a hole can be made by driving a pipe through the stemming, assisting the progress by a water jet, and blowing the material within the pipe out with compressed air. Or the bottom of the pipe can be closed with a sharp wooden plug and driven to within a few inches of the missed charge, if its location is known. A new primer is then lowered into the pipe and fired. This will usually detonate the missed charge.

When it is not possible to make a hole down through the

stemming or to wash the stemming out of the hole, it may be necessary to open the missed hole and unload the stemming by benching. Small diameter holes are drilled vertically 5 or 6 ft deep in front of and to the side of the missed hole so that the top 5 or 6 ft of the main quarry face may be blasted off to expose the hole. This new bench is cleaned and the operation repeated until it is possible to prime the missed charge and shoot it. It will probably be necessary to drill the small holes within 2 or 3 ft of the missed hole and there is a possibility that the explosion of these small charges may set off the failed hole. It is, therefore, important that each bench shot be treated as though the entire missed charge were expected to shoot.

The above procedure reduces the burden on the top of the hole so that it is usually advisable to pile several tons of rock against the face to reduce the throw of the stone. If the face is too high for this treatment, it may be necessary to remove the dynamite from the upper portion of the hole; this is very hazardous work and should be done only as a last resort and under the direction of a representative of the explosives manufacturer.

When a drill hole in a quarry has missed and the adjoining holes have robbed the burden from the missed hole, it is generally safer to fire the hole, taking necessary precautions against possible damage from flying rock, than to attempt to dig out the explosive.

Some operators handle missed holes by drilling another hole far enough away for safe drilling, but close enough so that the explosion of the charge in the new hole detonates the missed one by propagation. Close attention must be paid to the location and direction of the second hole to eliminate the possibility of hitting the missed charge with a drill. It is preferable when possible to place the second hole so that both holes lie in a plane parallel to the face or so that the second one is in front of, rather than behind, the missed hole in order to prevent throwing unexploded dynamite into the debris from the blast. Many accidents have been caused by striking unexploded dynamite in the blasted material. In certain states the mining laws require that missed holes be handled in this manner.

With well drill holes or with holes that have been sprung, it is neither safe nor practicable to drill another hole near them to blast out the charge.

Keen observation in the investigation of a misfire will usually disclose the cause of the trouble, such as improperly

made primers, use of non-water resistant explosives in wet work, improper loading practices, injuries to fuse or leg wires, failure to light the fuse, or to connect the cap, or an improper electrical hook-up for the power available.

Occasionally misfires will be encountered in which only a portion of the charge remains unexploded in the borehole. They should be handled in the same manner as those involving the entire charge. They are most frequently caused by cut-off holes in tunnels and shaft rounds, although they may be brought about by improper priming, deteriorated explosives, or improper loading, as when for instance, an excessive amount of "bug dust" is allowed to get between the cartridges. Methods of preventing misfires from causes other than cut-off holes are described in Chapters VIII, IX, and X.

The elimination of unexploded dynamite in the muck pile or in the face when caused by cut-off holes is difficult, but much may be accomplished by priming the holes at or near the bottom, by making certain that all fuses are trimmed properly, or that the delay electric blasting caps are properly loaded so that the holes go in the logical rotation, by drilling the cut deeper than the rest of the round, by keeping the number of holes per round down to the minimum necessary to pull the burden, and by designing the round with due consideration to all visible seams and partings.

BURNING OR DELAYED SHOTS

It should be mentioned further that many of the errors in procedure that cause misfires and partial misfires may also cause all or part of the charge to burn. When the detonation wave is too weak to explode the charge, it frequently sets it on fire. If a burning charge is seen or suspected, the location should not be approached for at least one hour, as such holes have been known to burn as long as 45 minutes and then explode. As previously mentioned, the fumes from burning dynamite are very toxic so that the place should be well ventilated before the men enter it.

NOTE:—The blaster is also referred to the list of "Don'ts" in Appendix IV covering many sources of possible trouble in blasting, and the further nformation on fumes in Appendix V.

APPENDIX I

INFORMATION TABLES

TABLE XXI

Strength of "Nitramon"

Approximate Number of Pounds of "Nitramon" Equal in Energy to 100 Pounds of Various Explosives.

DYNAMITE GRADES	LB OF "NITRAMON" A, B, C OR D
Special Gelatin 75%	97
Special Gelatin 60%	87
Special Gelatin 50%	76
Special Gelatin 40%	71
"Red Cross Extra" 60%	93
"Red Cross Extra" 50%	86
"Red Cross Extra" 40%	78
"Gelex" No. 1 and No. 2	99
Du Pont "Extra" A, B, C, and D	102
Du Pont "Extra" F	99
Du Pont "Extra" H	95
"Red Cross" Blasting No. 2 F. R.	59
"Red Cross" Blasting No. 4 F. R.	76
"Red Cross" Blasting No. 5 F. R.	98

TABLE XXII
American Table of Distances

Blasting and Electric Blasting Caps		Other Explosives		Inhab'd Bldgs Barri-caded* (Feet)	Public Railway Barri-caded* (Feet)	Public High'y Barri-caded* (Feet)
Number Over	Number Not Over	Pounds Over	Pounds Not Over			
1,000	5.000			15	10	5
5.000	10,000			30	20	10
10,000	20,000			60	35	18
20.000	25,000		50	73	45	23
25.000	50.000	50	100	120	70	35
50,000	100,000	100	200	180	110	55
100,000	150,000	200	300	260	155	75
150.000	200,000	300	400	320	190	95
200,000	250.000	400	500	360	215	110
250,000	300,000	500	600	400	240	120
300.000	350,000	600	700	430	260	130
350,000	400,000	700	800	460	275	140
400,000	450.000	800	900	490	295	150
450,000	500.000	900	1,000	510	305	155
500,000	750,000	1,000	1,500	530	320	160
750,000	1,000,000	1,500	2,000	600	360	180
1,000,000	1,500.000	2,000	3,000	650	390	195
1,500,000	2,000,000	3,000	4.000	710	425	210
2,000,000	2,500,000	4,000	5.000	750	450	225
2,500,000	3,000,000	5,000	6,000	780	470	235
3,000,000	3,500,000	6,000	7,000	805	485	245
3,500,000	4,000,000	7,000	8,000	830	500	250
4,000,000	4,500,000	8,000	9,000	850	510	255
4,500,000	5,000,000	9,000	10,000	870	520	260
5,000,000	7,500,000	10,000	15,000	890	535	265
7,500,000	10,000.000	15,000	20,000	975	585	290
10,000,000	12,500,000	20,000	25,000	1,055	635	315
12,500,000	15,000.000	25,000	30,000	1,130	680	340
15,000,000	17,500,000	30,000	35,000	1,205	725	360
17,500,000	20,000,000	35,000	40,000	1,275	765	380
		40,000	45,000	1,340	805	400
		45,000	50,000	1,400	840	420
		50,000	55,000	1,460	875	440
		55,000	60,000	1,515	910	455
		60,000	65,000	1,565	940	470
		65,000	70,000	1,610	970	485
		70,000	75,000	1,655	995	500
		75,000	80,000	1,695	1,020	510
		80,000	85,000	1,730	1,040	520
		85,000	90,000	1,760	1,060	530
		90,000	95.000	1,790	1,075	540
		95,000	100,000	1,815	1,090	545
		100,000	125.000	1,835	1,100	550
		125,000	150,000	1,900	1,140	570
		150,000	175,000	1,965	1,180	590
		175,000	200,000	2,030	1,220	610
		200,000	225,000	2,095	1,260	630
		225,000	250,000	2,155	1,295	650
		250.000	275,000	2,215	1,330	670
		275,000	300,000	2,275	1,365	690
		300,000	325,000	2,335	1,400	705
		325,000	350,000	2,390	1,435	720
		350,000	375,000	2,445	1,470	735
		375,000	400,000	2,500	1,500	750
		400,000	425,000	2,555	1,530	765
		425,000	450,000	2,605	1,560	780
		450,000	475,000	2,655	1,590	795
		475,000	500,000	2,705	1,620	810

*Barricaded, as here used, signifies that the building containing explosives is screened from other buildings, railways, or from highways by either natural or artificial barriers. Where such barriers do not exist, the distances should be doubled.

TABLE XXIII

Resistance in Ohms of Electrical Firing Devices*

KIND OF WIRE	COPPER	COPPER	COPPER	COPPER	IRON	IRON
Length of Wire in Feet	Regular and Waterproof Electric Blasting Caps	Seismograph Electric Blasting Caps	Delay Electric Blasting Caps	Regular Squibs and Delay Electric Squibs and Igniters	Electric Blasting Caps	Delay Electric Blasting Caps, Regular and Delay Electric Squibs and Igniters
4	1.26	1.49	1.22	1.04	1.99	1.73
6	1.32	1.53	1.29	1.10	2.39	2.14
7	....	....	....	....	2.60	2.35
8	1.38	1.57	1.35	1.17	2.80	2.55
9	....	....	....	....	3.01	2.75
10	1.45	1.62	1.43	1.23	3.22	2.95
12	1.52	1.66	1.51	1.30	3.64	3.35
16	1.65	1.74	1.65	1.43	....	....
20	1.79	1.83	1.79	1.56	....	....
24	1.93	1.91	1.93	1.71	....	....
30	1.76	2.04	1.65	1.54	....	....
40	1.97	2.26	1.86	1.75	....	....
50	2.18	2.47	2.06	1.96	....	....
60	2.35	2.69	2.26	2.16	....	....
80	2.73	3.12	2.66	2.57	....	....

*Subject to a variation of plus or minus 0.25 ohm

TABLE XXIV

Pounds of Du Pont Explosives per Foot of Hole—When Cartridges Are Slit and Well Tamped

Borehole Diameter Inches	Straight	"Red Cross Extra"	Gelatin	"Gelex" No. 1	"Gelex" No. 2	Du Pont "Extra"						"Red Cross" Blasting Free Running				"B" Blasting Powder
						A	B	C	D	F	H	No. 2	No. 3	No. 4	No. 5	
1	.42	.40	.47	.42	.38	.39	.37	.35	.34	.30	.26	.33	.32	.30	.29	.34
1¼	.64	.62	.72	.64	.61	.62	.59	.56	.54	.47	.41	.54	.50	.46	.45	.52
1½	.95	.91	1.05	.95	.88	.90	.85	.82	.78	.68	.60	.75	.72	.66	.65	.76
1¾	1.27	1.22	1.42	1.27	1.20	1.22	1.15	1.11	1.07	.92	.81	1.02	.98	.90	.88	1.02
2	1.65	1.58	1.84	1.64	1.54	1.57	1.48	1.42	1.36	1.18	1.04	1.35	1.29	1.20	1.16	1.32
2½	2.55	2.45	2.84	2.55	2.44	2.50	2.35	2.26	2.17	1.87	1.66	2.08	2.00	1.84	1.80	2.04
3	3.75	3.60	4.17	3.74	3.53	3.60	3.39	3.27	3.14	2.70	2.40	3.00	2.89	2.71	2.66	3.00
3½	5.10	5.28	5.68	5.08	4.62	4.91	4.62	4.44	4.27	3.67	3.26	4.08	3.93	3.62	3.53	4.08
4	6.60	6.83	7.35	6.58	5.90	6.27	5.90	5.68	5.46	4.70	4.17	5.28	5.13	4.74	4.65	5.28
4½	8.40	8.70	9.35	8.38	7.51	7.98	7.51	7.23	6.95	5.99	5.30	6.73	6.50	5.96	5.82	6.72
5	10.50	10.88	11.69	10.48	9.42	10.01	9.42	9.07	8.71	7.51	6.65	8.21	8.10	7.37	7.20	8.40
5½	12.6	13.07	14.0	12.58	10.60	11.26	10.60	10.20	9.80	8.45	7.49	10.1	9.68	8.90	8.70	10.1
6	15.0	15.55	16.7	14.98	13.57	14.42	13.57	13.06	12.55	10.81	9.58	11.8	11.5	10.6	10.4	12.0
6½	17.5	18.15	19.5	17.47	15.93	16.92	15.93	15.33	14.73	12.68	11.25	13.8	13.5	12.5	12.2	14.0
7	20.4	21.16	22.7	20.38	18.47	19.63	18.47	17.78	17.09	14.72	13.05	16.1	15.7	14.5	14.2	16.3
8	26.7	27.6	29.7	26.6	23.5	25.0	23.5	22.7	21.8	18.8	16.7	21.0	20.4	18.9	18.4	21.4
9	33.7	35.0	37.6	33.7	30.0	32.0	30.0	29.0	27.6	24.0	21.2	26.5	25.8	23.9	23.4	27.0
10	41.7	43.2	46.4	41.6	37.7	40.0	37.7	36.2	34.8	30.0	26.6	32.8	32.0	29.5	28.8	33.4
11	50.4	52.2	56.1	50.3	42.4	45.0	42.4	40.8	39.2	33.8	30.0	39.6	38.6	35.7	34.9	40.3
12	60.0	62.2	66.8	59.9	54.2	57.6	54.2	52.2	50.0	43.2	38.3	47.0	45.9	42.5	41.6	48.0

The above figures vary according to conditions. In holes drilled by air hammer machines this table would hardly apply as all holes drilled in that manner have a taper.

When the cartridges are smaller in diameter than the diameter of the boreholes and are not slit, the above figures would not apply even though the cartridges were well tamped.

TABLE XXV
Determining Height of a Quarry Face

Data for Use in Conjunction with Method Shown in Figure 158, Page 209

Light-face figures show AB or 45° line in feet.
Dark-face figures show AC or BC leg of triangle in feet.

16	**11**	61	**43**	106	**75**
17	**12**	62	**44**	107	**76**
18	**13**	63	**45**	108	**76**
19	**14**	64	**45**	109	**77**
20	**14**	65	**46**	110	**78**
21	**15**	66	**47**	111	**78**
22	**16**	67	**47**	112	**79**
23	**16**	68	**48**	113	**80**
24	**17**	69	**49**	114	**81**
25	**18**	70	**50**	115	**81**
26	**18**	71	**50**	116	**82**
27	**19**	72	**51**	117	**83**
28	**20**	73	**52**	118	**83**
29	**20**	74	**52**	119	**84**
30	**21**	75	**53**	120	**85**
31	**22**	76	**54**	121	**86**
32	**23**	77	**54**	122	**86**
33	**23**	78	**55**	123	**87**
34	**24**	79	**56**	124	**88**
35	**25**	80	**57**	125	**88**
36	**25**	81	**57**	126	**89**
37	**26**	82	**58**	127	**90**
38	**27**	83	**59**	128	**91**
39	**28**	84	**59**	129	**91**
40	**28**	85	**60**	130	**92**
41	**29**	86	**61**	131	**93**
42	**30**	87	**62**	132	**93**
43	**30**	88	**62**	133	**94**
44	**31**	89	**63**	134	**95**
45	**32**	90	**64**	135	**95**
46	**32**	91	**64**	136	**96**
47	**33**	92	**65**	137	**97**
48	**34**	93	**66**	138	**98**
49	**35**	94	**66**	139	**98**
50	**35**	95	**67**	140	**99**
51	**36**	96	**68**	141	**100**
52	**37**	97	**68**	142	**100**
53	**37**	98	**69**	143	**101**
54	**38**	99	**70**	144	**102**
55	**39**	100	**71**	145	**103**
56	**40**	101	**71**	146	**103**
57	**40**	102	**72**	147	**104**
58	**41**	103	**73**	148	**105**
59	**42**	104	**74**	149	**105**
60	**42**	105	**74**	150	**106**

TABLE XXVI

Burdens—Number of Cubic Yards of Rock Displaced per Foot of Borehole

Average Burden on Boreholes	Spacing of Boreholes														
	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
6	1.33	1.55	1.77	2.0	2.22	2.44	2.65								
7	1.55	1.81	2.0	2.33	2.7	2.85	3.11								
8	1.77	2.0	2.37	2.65	2.96	3.26	3.55								
9	2.0	2.33	2.65	3.0	3.33	3.66	4.0								
10	2.22	2.7	2.96	3.33	3.7	4.1	4.44	4.81	5.18	5.55	5.92				
11			3.26	3.66	4.1	4.48	4.88	5.3	5.7	6.11	6.52				
12				4.0	4.44	4.88	5.33	5.77	6.22	6.66	7.11				
13					4.81	5.3	5.77	6.26	6.74	7.22	7.70				
14					5.18	5.7	6.22	6.74	7.26	7.77	8.30				
15					5.55	6.11	6.66	7.22	7.77	8.33	8.88	9.44	10.0	10.55	11.11
16							7.11	7.70	8.30	8.88	9.48	10.07	10.66	11.3	11.85
17							7 55	8.18	8.81	9.41	10.07	10.70	11.33	11.96	12.59
18							8.0	8.66	9.33	10.0	10.66	11.33	12.0	12.66	13.33
19								9.15	9.85	10.55	11.3	11.96	12.66	13.37	14.07
20								9.63	10.37	11.11	11.85	12.59	13.33	14.07	14.81
21										11.66	12.44	13.22	14.37	14.77	15.55
22										12.22	13.03	13.85	14.66	15.48	16.30
23										12.78	13.63	14.48	15.33	16.18	17.03
24										13.33	14.22	15.11	16.0	16.88	17.77
25										13.88	14.81	15.74	16.66	17.60	18.51
26										14.44	15.74	16.37	17.33	18.30	19.25
27										15.0	16.15	17.0	18.0	19.0	20.0
28										15.55	16.6	17.63	18.52	19.7	20.74
29										16.1	17.18	18.26	19.33	20.4	21.48
30										16.66	17.77	18.88	20.0	21.1	22.22

NOTE:—To reduce to tons: For limestone, shale, granite, etc., multiply by 2¼; for trap rock, multiply by 2½; for sandstone, multiply by 2⅛.

TABLE XXVII

Burdens—Total Number of Cubic Yards of Rock Displaced by Borehole

Height of Face	Cubic Yards per Foot of Borehole (See Table XXVI)											
	2	4	6	8	10	12	14	16	18	20	22	24
14	28	56	84	112	140	168	196	224	252	280	308	336
16	32	64	96	128	160	192	224	256	288	320	352	384
18	36	72	108	144	180	216	252	288	324	360	396	432
20	40	80	120	160	200	240	280	320	360	400	440	480
22	44	88	132	176	220	264	308	352	396	440	484	528
24	48	96	144	192	240	288	336	384	432	480	528	576
26	52	104	156	208	260	312	364	416	468	520	572	624
28	56	112	168	224	280	336	392	448	504	560	616	672
30	60	120	180	240	300	360	420	480	540	600	660	720
32	64	128	192	256	320	384	448	512	576	640	704	768
34	68	136	204	272	340	408	476	544	612	680	748	816
36	72	144	216	288	360	432	504	576	648	720	792	864
38	76	152	228	304	380	456	532	608	684	760	836	912
40	80	160	240	320	400	480	560	640	720	800	880	960
42	84	168	252	336	420	504	588	672	756	840	924	1008
44	88	176	264	352	440	528	616	704	792	880	968	1056
46	92	184	276	368	460	552	644	736	828	920	1012	1104
48	96	192	288	384	480	576	672	768	864	960	1056	1152
50	100	200	300	400	500	600	700	800	900	1000	1100	1200
60	120	240	360	480	600	720	840	960	1080	1200	1320	1440
70	140	280	420	560	700	840	980	1120	1260	1400	1540	1680
80	160	320	480	640	800	960	1120	1280	1440	1600	1760	1920
90	180	360	540	720	900	1080	1260	1440	1620	1800	1980	2160
100	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400

NOTE:—Interpolate for values between those given.

TABLE XXVIII

Weights of Various Materials

Information principally from "Keystone Mining Catalog, Metal-Quarry Edition."

Material	Av. Wt. in Lb per Cu Ft	Material	Av. Wt. in Lb per Cu Ft
Brick		**Lime**—(Continued)	
Common red	100	Stone—large rocks	168
Fire clay	150	Stone—irregular lumps	96
Silica	128	**Masonry**	
Magnesia	160	Granite or limestone	165
Cement		Mortar—rubble	154
Portland	78	Mortar—dry	138
Hydraulic	60	Sandstone—dressed	144
Fine Ground Clays, Silica Cement		**Metals**	
Fire clay	85	Aluminum	166
Silica cement	75	Brass—cast	524
Magnesia cement	127	Bronze	534
Chrome cement	135	Copper—cast	537
Coal and Coke		Copper—rolled or wire	555
Anthracite	97	Iron—cast	450
Bituminous	84	Iron—wrought	482
Coke	62.5	Lead—cast	708
Concrete		Lead—rolled	711
Cement—fine	137	Steel—cast	490
Rubble—coarse	119	Steel—rolled	495
Earth		Tin—cast	459
Loam—dry, loose	76	Zinc—cast	438
Loam—packed	95	**Sand—Gravel**	
Loam—soft, loose mud	108	Dry, loose sand	100
Loam—dense	125	Dry, packed sand	110
Lime		Wet, packed sand	130
Quick—loose lumps	53	Gravel—packed	118
Quick—fine	75	**Water**	
		Water as ice	58.7
		Water 32° Fahr.	62.4

TABLE XXIX

Average Weight in Pounds per Unit of Volume of Different Materials Blasted

Information principally from "Handbook of Rock Excavation," by H. P. Gillette.

	Specific Gravity	Solid		Broken*	
		Cubic Foot	Cubic Yard	Cubic Foot	Cubic Yard
Basalt	3.01	188	5076	122	3299
Coal—Anthracite	1.3 —1.84	98	2546	64	2255
Coal—Bituminous	1.2 —1.5	84	2268	55	1474
Diabase	2.6 —3.03	176	4752	114	3089
Dolomite	2.8 —2.9	181	4887	117	3177
Gneiss	2.62—2.92	179	4833	116	3141
Granite	2.55—2.86	169	4563	110	2966
Gypsum	2.3 —3.28	174	4698	113	3054
Halite (Rock Salt)	2.1 —2.56	145	3915	94	2545
Hematite	4.5 —5.3	306	8262	199	5430
Limestone	2.35—2.87	163	4401	107	2861
Limonite	3.6 —4.0	237	6399	154	4159
Magnetite	4.9 —5.2	315	8505	205	5528
Marble	2.08—2.85	154	4158	100	2703
Mica-schist	2.5 —2.9	168	4536	109	2948
Porphyry	2.5 —2.6	159	4293	103	2790
Sandstone	2.0 —2.78	149	4023	97	2615
Shale	2.4 —2.8	162	4374	105	2843
Slate	2.5 —2.8	171	4617	111	3001
Talc	2.56—2.8	167	4509	108	2931
Trap	2.6 —3.0	174	4698	113	3054

* Figures under this heading are obtained by applying the following statement found on Page 12 of Gillette's "Handbook of Rock Excavation." "Hard broken stone from a rock crusher has about 35% voids if all sizes are mixed and slightly shaken down in a box."

APPENDIX II

TRADE MARKS

The following terms are trade marks exclusively owned by E. I. du Pont de Nemours & Co. (Inc.), and are used by it to designate some of its products which are used in blasting.

Explosives

"Agritol"	"Lump Coal"
"Chokhol"	"Monobel"
"Dittmar"	"Red Arrow"
"Duobel"	"Red Cross"
"Durox"	"Red Star"
"Forcite"	"Repauno"
"Gelex"	"Seismogel"
"Gelobel"	"S.N.G."

Blasting Agents

"Nitramon"

APPENDIX III

A SHORT BIBLIOGRAPHY OF EXPLOSIVES LITERATURE FOR BLASTERS

General Publications

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REPORT OF INVESTIGATIONS No. 3407—Earth Vibrations Caused by Mine Blasting.

REPORT OF INVESTIGATIONS No. 3431—House Movement Caused by Ground Vibrations.

REPORT OF INVESTIGATIONS No. 3509—Stemming in Metal Mines.

REPORT OF INVESTIGATIONS No. 3537—Annual Report of the Explosives Division, Fiscal Year 1940.

REPORT OF INVESTIGATIONS No. 3541—Diesel Engines Underground.

REPORT OF INVESTIGATIONS No. 3542—House Movement Induced by Mechanical Agitation and Quarry Blasting.

REPORT OF INVESTIGATIONS No. 3583—Active List of Permissible Explosives and Blasting Devices Approved Prior to June 30, 1941.

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INFORMATION CIRCULAR No. 7110—List of Permissible Mine Equipment Approved to January 1, 1940.

INFORMATION CIRCULAR No. 7115—Cars for Transporting Explosives.

INFORMATION CIRCULAR No. 7137—Some Information for Miners About Coal-Mine Ventilation.

INFORMATION CIRCULAR No. 7138—How Mine Workers Can Help to Prevent Mine Explosions.

INFORMATION CIRCULAR No. 7147—Problem of Accident Prevention at Small Metal Mines.

INFORMATION CIRCULAR No. 7158—List of Permissible Mine Equipment Approved During 1940.

APPENDIX IV

DON'TS

As Recommended by the Institute of Makers of Explosives

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1. DON'T store blasting caps, electric blasting caps, high explosives or blasting powder in a residence, home, boarding house or any other human habitation, or leave them lying around where children can get them.
2. DON'T leave explosives in a wet or damp place. They should be kept where it is clean, cool, dry and well ventilated.
3. DON'T leave explosives in a field or any place where stock can get at them. Cattle like the taste of salts in explosives, but these or other ingredients will probably make them sick or kill them.
4. DON'T store explosives so that the cartridges stand on end.
5. DON'T store explosives in or near a blacksmith shop, or near a stove.
6. DON'T open cases of explosives in a magazine.
7. DON'T throw packages of explosives violently down or slide them along floors or over each other or handle them roughly in any manner.
8. DON'T smoke while using or handling any explosives.
9. DON'T handle explosives near open lights, other fire or flame, or sparks.
10. DON'T have matches about you while handling explosives. Where matches are used to light the fuse, they should be contained in a closed metal box.
11. DON'T use any tool other than wooden wedges and wooden, fiber or rubber mallets for opening cases containing high explosives.
12. DON'T use blasting powder with permissible explosives or dynamite, nor dynamite with permissible explosives, in the same borehole in coal mines.
13. DON'T explode a charge to spring or chamber a borehole and then load another charge into it before it has cooled sufficiently.

14. DON'T force a cartridge of high explosives, especially a primer, into a borehole.
15. DON'T spring a hole adjacent to a loaded hole.
16. DON'T tamp with iron or steel bars or tools. Use only a wooden stick with no exposed metal parts.
17. DON'T allow explosives, or drill holes while being loaded with explosives, to be exposed to sparks that might come from steam shovels or locomotives in operation, or from any other source.
18. DON'T prime both ends of a cartridge of explosive, when making primers of half cartridges with a blasting cap or electric blasting cap, before cutting it in two. Cut the cartridge in half and prime each piece separately.
19. DON'T shoot into explosives with any firearm.
20. DON'T use damaged leading or connecting wire in blasting circuits.
21. DON'T connect up or load boreholes for electric firing during the approach or progress of a thunderstorm, and if charges are already loaded and connected, all persons should be kept at a safe distance from them while the storm is in progress. If necessary to leave overnight, ends of the wires should be twisted together, coiled and covered with dirt.
22. DON'T fire a blast before all persons are at a safe distance or under sufficient cover, and all explosives are in a safe place.
23. DON'T allow occupied automobiles near the danger area of the blast.
24. DON'T attempt to investigate a misfire too soon, even though it is thought the fuse has not been lighted or has gone out.
25. DON'T drill, bore or pick out a charge of explosives that has misfired. Where required by law, drill and charge another borehole at least two feet from the missed one. If this is done, make careful search for unexploded material in the debris. (In some cases, as in well drill, sprung or block holes, or others, it is often advisable to carefully remove the stemming or make a hole through it to within a safe distance of the charge of explosive, then reprime and explode the charge.) In general, misfires should be handled only by a competent and experienced man; the method employed should be in accordance with his best judgment.

26. DON'T keep blasting caps or electric blasting caps in the same box, container or magazine with other explosives.
27. DON'T light fuses in the vicinity of boxes of caps or other explosives.
28. DON'T leave packages of explosives or blasting caps uncovered.
29. DON'T leave high explosives, blasting caps or electric blasting caps exposed to the direct rays of the sun.
30. DON'T store or carry blasting caps or electric blasting caps with any other kind of explosives.
31. DON'T allow priming (placing of a detonator in the dynamite cartridge) to be done in a thawing house or magazine.
32. DON'T have electric wires or cables, which may be carrying current, near blasting caps or electric blasting caps, explosives or charged boreholes at any time except for the purpose of firing the blast.
33. DON'T use any blasting caps, or electric blasting caps, weaker than No. 6.
34. DON'T attempt to use electric blasting caps with plain wire and normal insulation in very wet work. For this purpose use waterproof electric blasting caps having enameled wires.
35. DON'T use electric blasting caps or other electric firing devices of different manufacture in the same circuit.
36. DON'T attempt to take blasting caps from a box by inserting a wire, nail or other sharp instrument.
37. DON'T attempt to remove or investigate the contents of a blasting cap or electric blasting cap.
38. DON'T carry blasting caps or electric blasting caps in pockets of clothing.
39. DON'T try to withdraw the wires from an electric blasting cap.
40. DON'T tap or otherwise investigate blasting caps or electric blasting caps.
41. DON'T spare force or energy in operating blasting machines.
42. DON'T store fuse in a hot place as this may injure the fuse and cause the waterproofing material to damage the powder train.

43. DON'T handle fuse carelessly in cold weather. When cold it is stiff and breaks easily. It should be warmed slightly before using. Avoid kinks in fuse and wires.
44. DON'T use short fuse. Cut fuse sufficiently long to extend beyond the collar of the hole and sufficiently long for safety in retiring from the blast. Never use less than two feet.
45. DON'T cut fuse on a slant, but cut it square across. Cut off an inch or two of fuse to insure having fresh end inserted in the blasting cap, and see that the fuse is seated against the detonating agent in the cap.
46. DON'T crimp blasting caps to fuse with a knife blade or with the teeth, but see that the blasting cap is securely attached to the fuse by means of a suitable cap crimper.
47. DON'T lace fuse through cartridges of explosives. This practice is frequently responsible for the burning of the charge, or misfires in wet work.
48. DON'T hold the primer cartridge in the hand when lighting fuse.
49. DON'T light fuse in any borehole or where the explosive charge in the hole or in adjacent holes has not been covered with sufficient stemming material to protect the explosives from sparks from the end spit of fuse or a flying match head.
50. DON'T try to light fuse with burning paper or other inflammable refuse.
51. DON'T use empty dynamite boxes for kindling.
52. DON'T light fuses in the vicinity of boxes of caps or other explosives.
53. DON'T permit any paper product used in the packing of explosives to leave your possession. Accumulations of fibreboard boxes, paper case liners, or cartons, or cartridge paper should be destroyed by burning.
54. DON'T tamper with or change the circuit of a blasting machine in any way for any purpose.
55. DON'T use any means other than a blasting galvanometer containing silver chloride cell for testing electric blasting caps or blasting circuits.

APPENDIX V

FUME CLASSIFICATIONS

A. Permissible Dynamites—U. S. Bureau of Mines

Fume Class	Liters Poisonous Gases Per 1½ Lb of Explosive	Cubic Feet Poisonous Gases Per 1 Lb of Explosive
A	Less than 53	Less than 1.87
B	53 to 106	1.87 to 3.74
C	106 to 158	3.74 to 5.58

B. Dynamites other than Permissibles—Institute of Makers of Explosives

Fume Class	Cubic Feet Poisonous Gases Per (1¼" x 8") Cartridge of Explosive
1	Less than 0.16
2	0.16 to 0.33
3	0.33 to 0.67

In both of the above classifications the amount of poisonous gases produced by an explosive is determined by detonating the explosive in the Bichel Gauge. A 1¼"x 8" cartridge or approximately 200 gm of explosive with wrapper corresponding to that on a 1¼"x 8" cartridge is tested.

Suggestions for Minimizing Production of Poisonous Gases from Explosives—Institute of Makers of Explosives

1. Use the largest diameter cartridge of explosive which is consistent with the work to be done. Preferably explosives of not less than 1⅛ in. in diameter should be used.
2. Avoid the use of explosives which have deteriorated due to moist, unduly prolonged, or other harmful storage.
3. Explosives should be shot in the wrappers supplied. Do not remove wrappers from an explosive or add paper or other combustible material to the charge.

4. Do not overcharge. Explosives used in excess of needs cause increased proportions of poisonous gases.

5. In wet work always use an explosive having adequate water resistance and fire the blast as soon after loading as practicable.

6. Avoid all conditions which may cause burning rather than detonation of the explosives, as for example, breaks in the explosive column, separation of the primer from the remainder of the charge, a poorly crimped cap which permits the fuse to be pulled out of the cap, or the use of explosives or caps which have deteriorated. Detonators of at least No. 6 strength should be used and should be kept as dry as possible before use.

7. In wet work use properly waterproofed cap and fuse assembly or electric blasting caps of adequate water resistance.

8. Confine the charge properly with non-combustible stemming, preferably moist sand, moist sand and clay, or other material of similar consistency. Proper confinement not only increases the efficiency of the explosive, but also tends to minimize the amount of poisonous gases produced.

E. I. DU PONT DE NEMOURS & CO. (INC.)

EXPLOSIVES DEPARTMENT

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GENERAL OFFICES

WILMINGTON, DELAWARE . . . . . . Nemours Building

BRANCH OFFICES

BIRMINGHAM, ALABAMA
Brown-Marx Bldg. . . . . . . 2000 First Ave.

CHICAGO, ILLINOIS
McCormick Bldg. . . . . . . 332 S. Michigan Ave.

DENVER, COLORADO
Midland Savings Bldg. . . . 444 Seventeenth St

DULUTH, MINNESOTA
Hartley Bldg. . . . . 742 E. Superior St.

HUNTINGTON, WEST VIRGINIA
West Virginia Bldg. . . . . 4th Ave. and 9th St.

JOPLIN, MISSOURI
Joplin Nat'l Bank Bldg. . . . . . 402 Main St

JUNEAU, ALASKA
Old 1st Nat'l Bank Bldg. . . . Front & Seward Sts.

KANSAS CITY, MISSOURI
City Bank Bldg. . . . . 1805 Grand Ave.

NEW YORK, NEW YORK
14th Floor Empire State Bldg. . . . 350 Fifth Ave.

PITTSBURGH, PENNSYLVANIA
Gulf Bldg. . . . . Grant St. and 7th Ave.

POTTSVILLE, PENNSYLVANIA
Schuylkill Trust Bldg. . . Centre and Market Sts.

SAN FRANCISCO, CALIFORNIA
One Eleven . . . . Sutter Street

SCRANTON, PENNSYLVANIA
1st Nat'l Bank Bldg. . . . . . 207 Wyoming Ave.

SEATTLE, WASHINGTON
Hoge Bldg. . . . . 701–705 Second Ave.

SPOKANE, WASHINGTON
Old Nat'l Bank Bldg. . . Riverside Ave. & Stevens St.

WILKES-BARRE, PENNSYLVANIA
Brooks Bldg. . . . . 15 S. Franklin St.